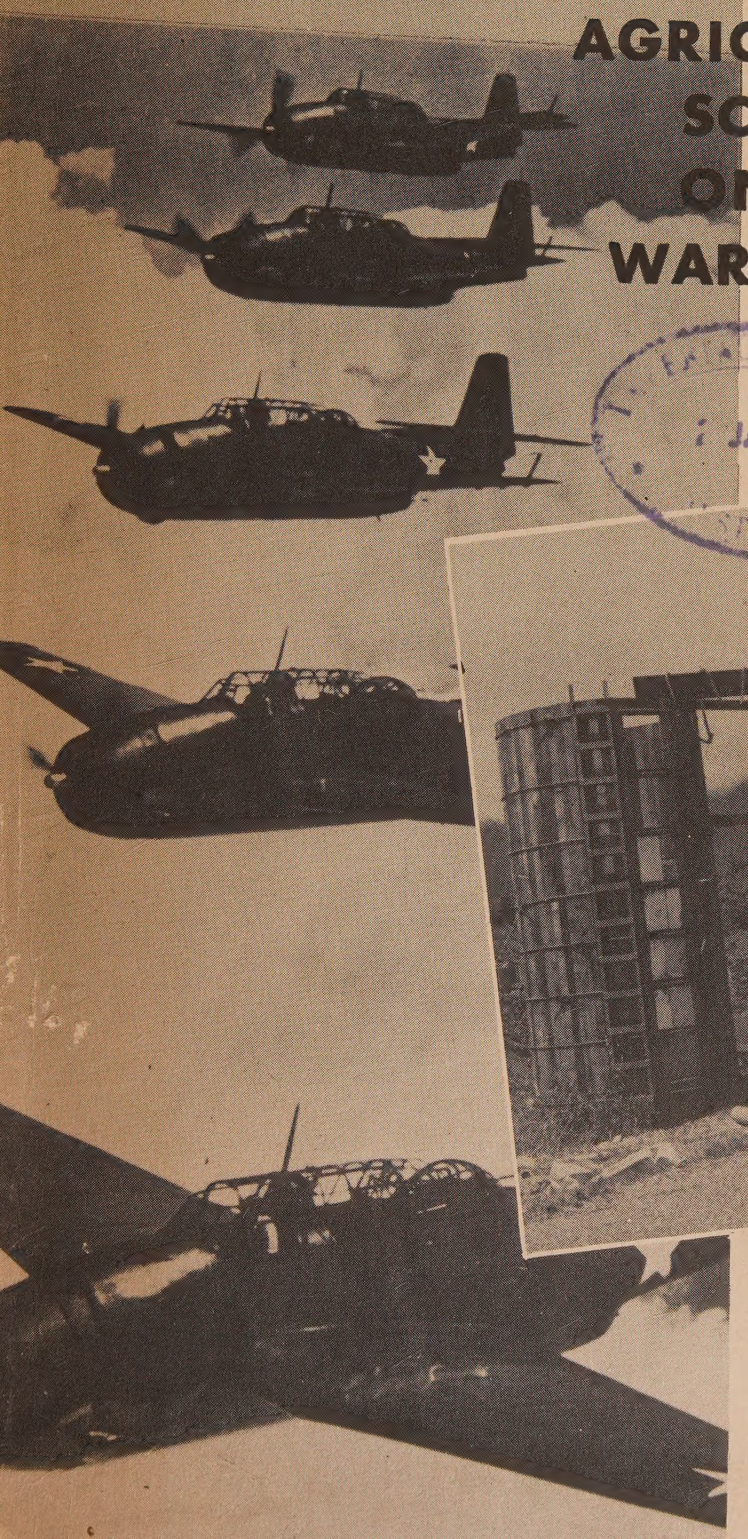
AGRICULTURAL SCIENCE ON THE WAR FRONT



JAN 1946

HAWAII AGRICULTURAL EXPERIMENT STATION 1941, 1942 REPORT

HAWAII AGRICULTURAL EXPERIMENT STATION, UNIVERSITY OF HAWAII

GREGG M. SINCLAIR, M.A. . . . . President of the University
J. H. BEAUMONT, Ph.D. . . . Director of the Experiment Station

ADMINISTRATION: L. A. HENKE, M.S., Assistant Director—H. K. HEE, Administrator.

AGRONOMY: J. C. RIPPERTON, M.S., Agronomist—E. Y. HOSAKA, M.S., Junior Agronomist—M. TAKAHASHI, M.S., Junior Agronomist—GORDON SHIGEURA, B.S., Assistant in Agronomy.

ANIMAL HUSBANDRY: L. A. HENKE, M.S., Animal Husbandman—S. H. WORK, Ph.D., Associate Animal Husbandman—C. I. MARUYAMA, B.S., Assistant in Animal Husbandry.

CHEMISTRY AND SOILS: L. A. DEAN, Ph.D., Associate Chemist—A. S. AYRES, M.S., Assistant Chemist—RUTH YOSHIDA, M.A., Associate in Chemistry—TAKUMA TANADA, B.S., Assistant in Chemistry—H. A. WADSWORTH, B.S., Collaborator.

ENTOMOLOGY: F. G. HOLDAWAY, Ph.D., Entomologist—W. LOOK, B.S., Associate in Entomology—T. NISHIDA, B.S., Junior Assistant in Entomology.

HORTICULTURE: J. H. BEAUMONT, Ph.D., Horticulturist—W. W. JONES, Ph.D., Assistant Horticulturist—W. B. STOREY, Ph.D., Assistant Horticulturist—WARREN IKEDA, B.S., Assistant in Horticulture—LILY SHAW, M.S., Assistant in Horticulture.

NUTRITION AND HISTOLOGY: CAREY D. MILLER, M.S., Nutritionist—*MARTHA POTGIETER, Ph.D., Associate Nutritionist—LAURA LEE, B.A., Assistant in Nutrition—KISAKO H. YANAZAWA, Junior Assistant in Nutrition.

PARASITOLOGY: J. E. ALICATA, Ph.D., Parasitologist—A. C. CUCKLER, Ph.D., Assistant Parasitologist.

PLANT PHYSIOLOGY: H. F. CLEMENTS, Ph.D., Plant Physiologist—E. K. AKAMINE, M.S., Associate in Plant Physiology—T. KUBOTA, B.S., Junior Assistant in Plant Physiology.

POULTRY HUSBANDRY: C. M. BICE, B.S., Poultry Husbandman.

TRUCK CROPS AND PLANT DISEASES: W. A. FRAZIER, Ph.D., Associate Horticulturist—*G. K. PARRIS, Ph.D., Associate Plant Pathologist—K. KIKUTA, B.S., Associate in Plant Pathology—M. MATSUURA, B.S., Assistant in Plant Pathology—D. SUMIDA, B.S., Assistant in Truck Crops—S. T. TACHIBANA, Junior Assistant in Truck Crops.

BRANCH STATIONS AND FARMS: R. K. PAHAU, B.S., Agricultural Scientist, Kona Branch Station—FRANK MERCADO, Foreman, Poamoho Experimental Farm—K. MURAKAMI, Foreman, Haleakala Branch Station—FRANK T. MURPHY, B.S., Collaborator.

---

* On leave of absence.

Digitized by the Internet Archive
in 2025

https://archive.org/details/report-agricultural-experiment-station-hawaii_1941-1942

Agricultural Science on the War Front

Report of the Hawaii Agricultural Experiment Station for the Biennium Ending June 30, 1942

by

J. H. BEAUMONT, *Director*

Published April 1943 by the University of Hawaii Honolulu, U. S. A.

Frontispiece.—That luxuriant growth of greens is possible at low elevations even during the summer is shown in the picture above, taken at the University of Hawaii farm in mid-July. Crops include various types of green and white mustards, Chinese cabbage, Chinese and New Zealand spinach, turnips, and five varieties of chard.

Table of Contents

	Page
Introduction	5
Animal Investigations	10
Cattle and Swine	10
Poultry and Rabbits	33
Parasitology Problems	44
Soil and Plant Investigations	52
Soil Studies	52
Plant Physiology	62
Agronomic Crops	69
Fruits and Nuts	85
Vegetable Crops and Diseases	98
Entomological Problems	111
Nutrition	130
Appendix	137
Publications	137
Active Projects	142
Fiscal Statement	149

Introduction

At this writing the United States has been at war for one year. Hawaii, the scene of the first actual attack on our material, social, and political rights, has undergone radical adjustments. The necessities of war have transformed this group of islands—and most especially Oahu—into an armed fortress. Essentially all civilian activities are affected by martial law and military urgencies; under repeated attack or siege, many civilians would become soldiers in fact.

To the country as a whole, Hawaii is at present primarily a combat zone. It has been bombed; the enemy on more than one occasion has given rather concrete evidence of its desire to resume the attack. The first objective of every person in Hawaii—civilians as well as members of the military forces—must be to guard against such an eventuality, even though the economy of the Islands may thereby be dislocated. On the other hand, there reside in the Territory a goodly number of civilians whose economic welfare is bound up in the future of the Islands, and who will, insofar as it does not jeopardize military security, work steadily for the preservation of the internal economy.

Hawaii is not self-sufficient under normal conditions, nor can it become so and maintain a reasonable standard of living. Its only important natural resources are an equitable climate, agricultural lands, and scenic beauty. The surrounding ocean has become less an asset than a liability at this time.

With raw sugar and canned pineapples as the chief export crops, Hawaii has established an agricultural economy whose favorable trade balance supplies its island residents with mainland gasoline, oil, automobiles, farm machinery, fertilizers, chemicals, shoes, clothing, foods, and other necessities, as well as many luxuries.

It has been estimated that to produce even the essential staple foods for the present population, with the land and labor available, would seriously undermine the established economy and destroy the credit balance necessary for purchase of essentials other than food.

Yet vital as the export crops of the sugar and pineapple industries are to the Territorial welfare, the internal economy is dependent on other agricultural enterprises as well. Large areas of land not employed by the two major crops are effectively utilized in producing much of our food supply,

and they provide employment and income to a considerable portion of the population.

Of especial importance is the beef industry, which occupies large acreages of presently nonarable land. The dairy industry is largely centered on Oahu, close to the only metropolitan market. The coffee, fruit, and truck-crop growers are concentrated in areas, on various islands, peculiarly adapted to the culture of specialized crops. The poultry and swine growers are more generally distributed, having small land requirements and being less restricted by climate and topography.

Except for the dairy and beef industries, these other agricultural enterprises are in the hands of small growers, and production methods are largely determined by the relatively small size of most units.

These industries have contributed materially to the fresh-food requirements of the Territory. In normal times approximately 60 percent of the beef and almost all of the fresh pork needed for civilians are locally produced. All of the fresh milk and 40 percent of the eggs consumed are Hawaiian products. On the other hand, almost all of the lamb and mutton, the cured meats such as ham and bacon, and the manufactured dairy products are imported. Normally, only a small fraction of the fresh fruits and vegetables are grown in Hawaii. If we consider canned fruits and vegetables, which are imported in large quantities, the balance is much lower. None of the fats or concentrated animal feeds is produced, and only a small fraction of the rice—the only locally produced cereal.

The immediate problem, then, dictated by limitations of shipping, is one of supply for the greatly expanded local food markets. The national economy, military necessity, or enemy action will determine in what measure this market must be supplied from local sources. Additional land and labor for diversified crops in the quantities that may be required can be secured only at the expense of sugarcane and pineapple culture. For diversified crops, proportionately more labor than land would be siphoned away from the two major crops, and labor is already at a premium. The knowledge, skill, and machinery for producing food crops on a large scale are definitely limited. Thus, a sudden readjustment of the agricultural ratios, if it becomes necessary, cannot be expected to be economically advantageous to the Territory or even to offer a complete solution to the problem.

On the other hand, and aside from the immediate war situation, agriculture in Hawaii is not static. Changes result not only from intensive development of the two major crops but also from improvements in other crops and in the methods of their culture. The possibilities for such improvements are great. They include development and maturing of the smaller

agricultural enterprises; the improvement of pastures through cultivation of the varieties and types of forage grasses best adapted to each zone or climatic condition; the greater development and use of soilage crops, together with mechanization of their handling; and the integration of the culture of additional economic crops into a gradually changing sugarcane, pineapple, and livestock economy. Intercycle plantings of potato and tomato in cane and pineapple rotations are examples of such integration. Others might be the development of profitable crops such as the macadamia, adapted to the marginal cane and pineapple lands, particularly in the wetter districts, and in the better pasture areas. Further, as knowledge of the cultural and economic potentialities of the papaya, mango, and litchi increases, it is very possible that suitable lands may be given over to their culture.

Only a few crops have been mentioned, and yet it is safe to say that every economically important tropical crop is present in the Territory and has been given some consideration. Rubber, sisal, ramie, quinine, tung oil, coconut oil, castor oil, rotenone, cassava starch, and other agricultural products are much in the news because mainland imports have been reduced or cut off. The Territory could even now be an important source of several or many of these—and on lands not utilized by the major crops. That it is not, is due to the absence of a long-term, constructive land-utilization policy, founded on research. Private capital and individuals should not be expected to take the initiative in endeavors which may be vital to the general welfare but do not show reasonable expectations of not too distant returns. Public support and cooperation among public agencies are essential.

It is the common and commendable policy of state experiment stations to devote much, if not most, of their effort to research directly related to the agricultural enterprises of major importance to their particular states. In Hawaii, however, each of the two major industries finances a well-staffed experiment station. Cooperation and exchange of scientific information and facilities are the rule and give evidence that sciences may not be segregated on a crop basis. To the Hawaii Agricultural Experiment Station, however, are allotted the problems of the divers other agricultural enterprises; the approach to these may be as scientific and fundamental, and the facts uncovered of as great significance, as those pertaining to sugarcane and pineapple.

There are potentialities in many of the tropical crops to be brought out only through study and research. These potentialities should, during this time of need, be explored to the limit of our available resources, with the anticipation that they will contribute to the immediate need and to the probably uncertain economy following the war.

The Hawaii Agricultural Experiment Station devotes its major efforts to problems such as these. It is the purpose of this report to summarize and draw together the results of our various activities in such a way that their application may be apparent. The discussion of each phase is, of necessity, brief. For those interested in specific investigations, more detailed statements will usually be found in bulletin or mimeographed form.

To many it must seem that the activities of the station are so scattered and so diverse that progress will be slow. This may be true in some instances, but one must recognize that diversified agriculture in the Territory is extremely comprehensive.

In addition to conducting the formal research of the station, individual members of the staff have contributed unstintingly of their knowledge to the emergency problems involved in the local production of food and feeds. The practical experience of individual staff members, gained through years of investigation and study, has been made available in public lectures, short courses, and radio broadcasts; through membership on committees advisory to the Military Governor on food production and nutrition and on committees representing the beef, dairy, swine, and poultry interests; and by specific recommendations on parasites, seed germination, desiccation of blood plasma, camouflage plants, etc. Those in charge of vegetable investigations have been in the field almost continuously since the outbreak of the war advising on the problems of the vegetable-production program inaugurated by the Office of the Military Governor. F. T. Murphy, formerly superintendent of the Poamoho Experimental Farm, was released to the Maui Food Administrator and later became Extension County Agent for Maui, where he has now assumed charge of the food and feed production program.

It is unfortunate that the experiment station staff has been seriously depleted, so that the war burden has fallen even more heavily on those remaining. Dr. G. K. Parris and Dr. Martha Potgieter, on sabbatic leave, were unable to return to the Territory. Dr. L. E. Harris and Dr. E. M. Hodges resigned to accept positions on the Mainland, and the vacancies were not filled because of financial conditions developing from the war. E. T. Fukunaga resigned to become county agent on Hawaii. Many of our technical assistants have accepted more remunerative positions in the Territory. These include T. Togashi, Ethel Lucas, D. Y. Sumida, Lucille Louis, Toyo Kimura, and K. W. Pierson. More recently we announced with regret the resignation of Dr. S. H. Work, who is joining the staff of the United States Department of Agriculture, Office of Foreign Agricultural Relations, and will be stationed at Nicaragua.

Dr. J. E. Alicata was released from certain experiment-station duties to assume charge of a public-health research project sponsored by the Chamber of Commerce of Honolulu. Dr. A. C. Cuckler came from the Mainland to carry the research work in parasitology during this period.

We were extremely fortunate in securing the services of Dr. W. A. Frazier as associate horticulturist in charge of vegetable crops and diseases. Mr. Arthur S. Ayres was added to the staff of the soils chemistry division through an agreement with the Experiment Station of the Hawaiian Sugar Planters' Association, and he has materially broadened our knowledge of Hawaiian soils through his research on base exchange and properties of acid soils. Dr. H. F. Clements, plant physiologist, is now devoting full time to research in the experiment station and will be able to develop further the important relationships of light, moisture, and mineral nutrients to growth and storage in plants. Promotions within the ranks, and additions to the staff, including Gordon Shigeura, T. Tanada, Y. Kanehiro, T. Nishida, and Bertha Mueller, have enabled the experiment station to maintain an efficient organization.

Animal Investigations

The animal industries constitute the third largest agricultural enterprise of the Territory, exceeded only by cane and pineapples in total value. The beef industry alone occupies more land than sugar or pineapples, and the 10,000,000 pounds of beef produced each year would normally supply about 60 percent of Hawaii's total consumption.

As range-fattened beef is almost independent of mainland supplies, any increase in production would be dependent only on improvement of pastures and pasture management and on pen fattening, utilizing soilage crops and pineapple and sugarcane byproducts. Pen fattening, however, would involve rather extensive changes: either the feeders would have to be imported or, if they were produced locally, a definite change in ranch management would be necessary. Also, it must still be conclusively demonstrated that methods of pen fattening with the variety of feeds available would be profitable.

Thus the beef-cattle industry presents many problems to the local producer and to the experiment station in ecology and management of pasture plants and soilage crops, breeding and nutrition of animals, management, and marketing. The nature and importance of the problems explain in large measure the emphasis placed upon them in this experiment station.

The dairy, swine, and poultry industries are more intensive than the beef industry and present a different set of problems, most important of which are sources and supplies of concentrated feeds.

CATTLE AND SWINE

In feeding cattle during this emergency, the chief problem is to provide proteinaceous supplements for our abundant carbohydrates, not only in order to maintain milk production but also to increase supplies of local beef by pen fattening. For this reason a very large proportion of experimental work in animal husbandry has been devoted to determining the most advantageous sources of protein. Other special phases of feeding discussed in this report include the evaluation of roughages for cattle and the utilization, particularly by swine, of various local byproducts.

DIGESTIBILITY STUDIES

Scientific feeding is based upon a knowledge of the nutritive requirements of livestock and the composition and digestibility of the principal constituents of the feeds or feed mixtures. In Hawaii many feeds and forages

not commonly utilized on the Mainland are fed to stock, even when exact information on their composition and digestibility is not available. Over a period of years the animal husbandry division of this station has accumulated scientific data on Hawaiian feeds. These are being assembled, and, when published as a station bulletin, should be of great value in compounding economical and efficient feed mixtures from local feeds.

Strip Cane

For some time the possibilities of strip cane as a feed for both dairy and beef cattle have been under consideration. Green cane tops have been used for years, but the partially dried leaves brought to the mill after burning and mechanical harvesting are a different type of material. Strip cane has recently been fed by several local dairymen, particularly during the period when eyespot disease destroyed large fields of Napier grass.

Composition and digestion coefficients of strip cane from the Waialua mill have been determined by a controlled feeding trial with four steers, as follows: Dry matter, 48—49 percent digestible; nitrogen-free extract, 23.6—55 percent digestible; crude fiber, 20.3—50 percent digestible; and ether extract, 0.5—32 percent digestible. Total digestible nutrients were equivalent to approximately 23.6 percent. The crude protein (1.28 percent) was not digestible. Total ash content was 2.29 percent.

The digestibility of strip cane in conjunction with concentrated feeds was also studied, by comparing a ration composed of strip cane plus concentrates with another composed of Napier grass plus concentrates. Two steers were fed each ration. Total digestible nutrients were 64 percent in the strip-cane and 65 percent in the Napier-grass ration. The digestion coefficients of the protein in the two rations were sufficiently comparable to permit the conclusion that when strip cane is a constituent of a balanced ration, some of its protein is made available for productive purposes. That this conclusion is warranted is borne out by the concurrent milk-production trial reported on page 24.

The results indicate that good-quality strip cane is almost comparable to Napier grass and, where readily available, might replace Napier grass. The area thus liberated could well be devoted to production of forages high in protein and other digestible nutrients. *(Work)*

Urea

Synthesis of proteins. In previous reports of the station and elsewhere, it has been pointed out that urea is utilized by ruminants, not directly but through bacteria in the rumen which convert the urea to proteins in their own bodies and which later are digested by the animal. Nonruminants do

not utilize urea, because their digestive systems do not permit the requisite bacterial action.

Eight steers which were ready for market provided an opportunity to prove this point further. For 10 days before slaughter, two lots of four steers each were fed equal quantities of the same low protein ration (2.6 percent protein). In the ration for one lot, however, urea was added to the extent of 14.6-percent protein equivalent (N $\times$ 6.25), bringing the total protein equivalent in the feed to 17.2 percent.

Five hours after the last feeding period the animals were slaughtered, and the rumen contents were analyzed separately. Rumen contents of the animals fed urea exceeded the contents of the check lot by 6 pounds protein per 100 pounds of dry matter, thus demonstrating a very rapid conversion from urea nitrogen to protein nitrogen. *(Harris, Work, Henke)*

Biological value of protein. The biological value of the protein derived from urea was compared to that of protein in soybean-oil meal, in a study to determine the amount of nitrogen used in repair and growth as against that required for maintenance alone.

Four steers, 6 to 8 months of age and weighing between 140 and 211 kilograms, were confined in the digestion barn, and the feces and urine were collected for total analyses. In the first and third of three feeding periods, the steers were fed a low-nitrogen basic ration consisting of 45 percent pineapple sirup, 14 percent raw sugar, 4 percent cottonseed oil, 15 percent sifted bagasse, 20 percent dried cassava meal, 1 percent salt, and 1 percent bonemeal. Each steer received 10 cubic centimeters of a vitamin A and D concentrate. The ration contained 1.44 percent protein and 80.8 percent dry matter. In the second period the same ration was fed except that portions of the cassava meal and raw sugar were replaced with urea or soybean-oil meal to increase the protein equivalent to between 12 and 13 percent.

The appetites of the animals always improved on the transition from the low-nitrogen basal ration to the urea-substituted or soybean-oil-meal-substituted ration. The animals lost weight in the low-nitrogen periods and gained weight in the high-nitrogen periods. The nitrogen balances were consistently negative (more nitrogen eliminated than was consumed) on the low-nitrogen ration, and positive on the urea or soybean-oil-meal ration. This result proves that the nitrogen from both urea and soybean-oil meal was being utilized and that the maintenance requirement was being satisfied.

A summary of the endogenous and metabolic nitrogen, digestion coefficients, and biological values is given in table 1. The endogenous nitrogen measures the net minimum maintenance requirement of nitrogen. It varied from 0.031 to 0.036 gram of nitrogen per kilogram of body weight, with an average of 0.0342 gram.

Table 1.—Comparison of endogenous and metabolic nitrogen, digestion coefficients, and biological values of protein derived from urea and that derived from soybean-oil meal

Steer number	Feed	Endogenous nitrogen per kgm. body weight[1]	Metabolic nitrogen per kgm. dry matter consumed[1]	Digestion coefficient[2]		Biological value[2]
				Apparent	True	
		Grams	*Grams*	*Percent*	*Percent*	*Percent*
10	Urea	0.036	4.85	76	95	24
11	Urea	.034	5.38	71	91	24
Average....		*.035*	*5.12*	*74*	*93*	*24*
9	Soybean-oil meal	.031	4.34	77	91	58
12	Soybean-oil meal	.036	5.00	78	94	51
Average....		*.0335*	*4.67*	*78*	*92*	*54*

[1] Average of periods 1 and 3.
[2] Period 2.

Strictly speaking, the metabolic nitrogen is a maintenance requirement too, but since it varies with the dry matter consumed, it is more logically charged to digestion. The metabolic nitrogen averaged 4.90 grams per kilogram of dry feed consumed.

The apparent digestion coefficient is the coefficient usually determined and includes the metabolic nitrogen in the feces, an inclusion which is logical since the metabolic nitrogen varies with dry matter consumed. The basal ration contributed 11.6 percent of the nitrogen when urea was fed, and 10.4 percent when soybean-oil meal was fed. Including this nitrogen, the digestion of urea nitrogen averaged 74 percent, and that of soybean-oil-meal nitrogen averaged 78 percent. The true digestion of nitrogen for urea averaged 93 percent; and for soybean-oil meal, 92 percent.

The biological value of urea was 24, and the average for that of soybean-oil-meal was 54, when fed at levels of 11- and 12-percent protein equivalent. The low value of urea in comparison with soybean-oil meal probably means that more urea was fed than could be utilized by the micro-organisms of the rumen. *(Harris, Work, Henke)*

BEEF CATTLE AND GROWING ANIMALS

Urea as a Protein Supplement

For growing heifers. It has been shown in digestibility studies (p. 11) that proteins derived from urea by micro-organisms in the rumen are actually utilized for maintenance and growth. Preliminary studies have also been made to determine the degree to which urea may effectively replace the protein concentrates normally fed.

In three separate tests, involving 15 dairy heifers ranging in age from 6 to 18 months, three levels of protein replacement by urea were studied. When urea equivalent to 4 percent of the total concentrates was fed, heifers did not grow quite so rapidly as animals receiving a normal protein ration, but did considerably better than a second check lot receiving no protein supplements. Heifers fed a 3-percent urea ration were irregular in growth, some doing as well as animals on the normal ration, but others less well. When a 1.5-percent urea ration was fed, the heifers gained as rapidly as those on the normal feed.

Apparently between 1.5 and 3 percent of a concentrated dairy feed may consist of urea. This urea replaces protein supplements at a considerable saving in cost, 1 pound of urea being equivalent in nitrogen content to about 7 pounds of soybean-oil meal.

Supplementing strip cane in pen fattening. In cooperation with the Diversified Crops Committee, Hawaiian Sugar Planters' Association, a pen-fattening experiment was conducted to determine whether urea could in part advantageously replace the more expensive cottonseed meal as a supplement to strip cane for beef cattle.

Several factors operated against the success of the experiment. The quality of the strip cane and the strip-cane silage fed, particularly during the early stages of the experiment, was poor. The consequent unpalatability of the roughage decreased total digestible-nutrient intake below the limiting level for desirable gains and increased molasses consumption to the point of causing diarrhea. Free access to bonemeal, a relatively expensive product, resulted in abnormally high costs of gains. For these reasons, the data presented below justify only conditional conclusions.

In this experiment, 19 Angus and 16 Hereford steers, each weighing around 470 pounds, were segregated in four lots and fed for 244 days as indicated in table 2.

Table 2.—Feed consumption of growing heifers in strip-cane feeding trials

Feeds	Average daily consumption of feeds			
	Lot 1	Lot 2	Lot 3	Lot 4
	Pounds	*Pounds*	*Pounds*	*Pounds*
Strip cane	12.0	19.0	19.0	19.0
Cane molasses	11.0	11.0	12.0	12.0
Cottonseed meal	3.7	3.7	3.0	2.2
Urea	.0	.0	.15	.35

Lots 1 and 2 received the same supplements of cottonseed-oil meal and molasses, but strip-cane feeding was limited in lot 1. Lots 2, 3, and 4 received the same quantities of strip cane, but in lots 3 and 4, urea replaced

approximately 20 and 40 percent, respectively, of the protein supplement (nitrogen-equivalent basis). These steers consumed 1 extra pound of molasses per head. Rates of gain and feed costs under these conditions are shown in table 3.

Table 3.—Rates of gain and feed costs in strip-cane pen-fattening tests

Lot	Average daily gain	Feed costs per pound of gain
	Pounds	*Cents*
1	1.23	9.46
2	1.36	8.75
3	1.35	8.36
4	1.04	10.67

It appears from the data in table 3 that the lower level of cane feeding (lot 1) was less satisfactory than the higher level (lot 2). The steers in lot 3, which received the smaller amount of urea, utilized the urea more economically than those in lot 4, which received the higher amount.

Attention should be called to the low carotene content of strip cane. The silage fed in this test contained only 0.56 part per million of carotene (precursor of vitamin A). To prevent occurrence of vitamin-A deficiency, sardine oil was added to the molasses at the rate of 3 cubic centimeters per steer per day. *(Work, Henke, Harris)*

In pasture fattening. Forage legumes are scarce or absent in many Hawaiian grazing areas, and cane molasses, the common pasture supplement, does not increase the protein level of the grasses. Whether or not available protein might be a limiting factor in rate of growth of beef cattle was tested at Kapapala Ranch, in cooperation with Manager B. M. Sumner, who had provided facilities for a number of previous experiments.

Five lots of 10 Hereford steers, each steer weighing approximately 750 pounds, were confined in separate pasture lots for 186 days and fed supplements as follows: Group 1, molasses only; group 2, 2.5 pounds urea per 100 pounds molasses; group 3, 5 pounds urea per 100 pounds molasses; group 4, molasses plus 0.85 pound cottonseed meal per head per day; group 5, molasses plus 1.64 pounds cottonseed meal per head per day. Inequalities in pasture were neutralized, as far as possible, by rotation at 5-week intervals.

Molasses consumption, which was approximately equal in all lots, averaged 0.8 percent of the live weights of the steers. Actual consumption of urea averaged 0.18 pound per steer per day in group 2, and 0.35 pound in group 3. Neither level of urea feeding produced gross injury to the livers or kidneys of the steers. Histological examinations confirmed these observations.

Rates of gain per head per day are shown below:

Lot 1	1.67 pounds	Lot 4	1.66 pounds
Lot 2	1.58 pounds	Lot 5	1.64 pounds
Lot 3	1.52 pounds		

In this experiment, nitrogen and protein supplements did not increase the rates of gain. The quality of the pastures remained constant or improved during the course of the experiment, a result which tends to confirm the conclusion that there was no protein deficiency in these particular grazing areas. *(Work, Harris, Henke)*

Yeast as a Protein Source

Yeast from molasses has received considerable attention as a potential source of protein for both humans and animals, because in an emergency it probably could be produced in quantity on most of the islands. Although production is still problematical, this station, in cooperation with the Experiment Station of the Hawaiian Sugar Planters' Association, has conducted a number of experiments to determine its food and feed value in various forms.

Two forms of yeast studied as livestock feed include a dried product comparable in protein content to soybean and cottonseed meals, and a slurry, prepared by centrifuging, that contains approximately 83 percent water and 6.9 percent protein. About 6 pounds of the slurry are equivalent in protein content to 1 pound of cottonseed meal. The dried yeast is presumably sterilized in the process of drying, while in the slurry the yeast is alive.

In a previous test (see 1940 annual report) it was found that dried yeast as the main source of protein gave as good or better gains than soybean and fish meals when fed to growing dairy heifers and fattening swine.

In two subsequent trials, employing 15 animals, yeast slurry mixed with molasses was fed at the average rate of 13 pounds slurry and 10 pounds molasses per head per day. The animals gained only 0.8 pound daily as against 1.5 pounds when soybean-oil meal was fed at the rate of 2 pounds in each 10 pounds of molasses.

It is apparent that factors other than nutritive value have affected these results. The mixture of yeast slurry and molasses totaled 23 pounds of liquid feed; the soybean mixture, only 12. The yeast slurry is not palatable, and difficulty was experienced in inducing the animals to eat the requisite amounts. There was evidence, too, that yeast slurry is more laxative than soybean meal. Future work may determine means of feeding yeast slurry in sufficient quantity to satisfy the protein requirements, perhaps by removing more water from the yeast. (See also pp. 19, 28, and 33 for further work with yeast.) *(Work, Henke, Maruyama)*

DAIRY CATTLE

The dairy industry, like the beef industry, contributes substantially to the subsistence of the Territory. The possibilities for expansion may be even greater than in the beef industry, for the annual milk production of 28,000,000 quarts is barely sufficient to supply fresh-milk requirements. However, dairying is a much more intensive form of agriculture than ranching, and the problems involved may consequently be more technical and acute. For example, when eyespot disease destroyed large acreages of Napier grass, the dairyman was in serious straits for suitable forage. Again, when the war interrupted shipping and protein concentrates were practically exhausted, dairying was threatened. In both instances the experiment station was of assistance; in the first by supplying disease-resistant types of Napier, and in the second by recommending with confidence the use of available protein substitutes.

The steady growth and improvement of the dairy industry has been due in no small measure to the work of this station. Demonstration of the value and proper use of pineapple bran, cane molasses, pineapple sirup, strip-cane forage, and numerous soilage and pasture crops has contributed to wide usage of these feeds by dairymen. (See also report of experiments in agronomy, pp. 71-83.) The work has continued steadily and is of special value during this time of acute consciousness of the importance of food production in the Territory.

Protein Supplements

Urea. It has been pointed out that urea may substitute for protein when fed to ruminants but that the amount is limited by the protein conversion power of micro-organisms in the paunch. Apparently between one-fourth and one-third of the total protein concentrate may be so replaced.

An experiment reported in 1940 has subsequently been carried to completion. Heifers fed urea in a growth trial continued through two lactation trials, with urea making up 3 percent of the total concentrate mixture. Feed consumed per pound of milk produced was approximately equal on the two rations. Live-weight gains were slightly superior on the urea ration. No off-flavors were noted in the milk, and the breeding behavior of the animals was normal.

The real significance of this work centers in the fact that the animals have been fed high percentages of urea from weaning through two pregnancies and lactations without any apparent deleterious effects.

When war focused attention on protein substitutes for dairy cows, this early work on urea was expanded. During the following 6 months, two 12-week, double-reversal tests on the effect of substituting urea for protein-concentrate feeds were completed.

The rations fed in the two trials were very similar, but unavailability of certain feeds necessitated minor changes. In the first trial, with 8 cows, 1.9 pounds of urea were substituted for 14.5 pounds of soybean-oil meal; in the second trial, with 12 cows, 1.5 pounds of urea were substituted for 10.7 pounds of soybean-oil meal. The composition of the rations fed in the two trials is summarized in table 4.

Table 4.—Rations fed in tests of urea as a substitute for protein concentrates

Feeds	First trial		Second trial	
	Control ration	Urea ration	Control ration	Urea ration
	Percent	*Percent*	*Percent*	*Percent*
Cane molasses	25.0	23.8	25.0	24.1
Pineapple bran	38.0	52.3	43.0	53.1
Coconut-oil meal	10.0	9.5	.0	.0
Soybean-oil meal	25.0	10.5	30.0	19.3
Urea	.0	1.9	.0	1.5
Steamed bonemeal	1.0	1.0	1.0	1.0
Salt	1.0	1.0	1.0	1.0
Totals	100.0	100.0	100.0	100.0

Results of the two trials are shown in condensed form in table 5.

Table 5.—Milk production, percentages of fat in milk, feed consumption, and weights of cows in urea-feeding trials

Concentrate ration	Average daily milk production	Fat content of milk	Average daily milk production (4-percent fat-corrected)	Average concentrates consumed daily	Average green Napier grass consumed daily	Average live weight of cows
	Pounds	*Percent*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Control:						
Trial 1	29.1	3.51	26.82	17.6	67.5	1,028
Trial 2	25.8	3.51	23.53	16.2	76.4	1,045
Average	*27.4*	*3.51*	*25.17*	*16.9*	*71.9*	*1,036*
Urea:						
Trial 1	27.5	3.60	25.75	17.5	68.0	1,025
Trial 2	24.7	3.66	23.23	16.2	73.7	1,050
Average	*26.1*	*3.63*	*24.49*	*16.8*	*70.8*	*1,037*

Urea intake averaged 0.33 pound per cow per day in the first trial, or 1.18 percent of the total dry-matter intake. In the second trial, average daily urea intake was 0.23 pound, an amount which was 0.84 percent of the total dry-matter intake.

Although differences in milk production in favor of the control rations averaged only 1.3 pounds per day (0.68 pound, fat-corrected), they were statistically significant. However, because of the material saving when urea

replaced high-cost protein supplements, the concentrate-feed cost of 4-percent-fat-corrected milk at then effective prices averaged 16.2 percent lower in the first trial and 20.2 percent lower in the second trial when the urea ration was fed. *(Henke, Work, Maruyama)*

Dried yeast. The potentialities of yeast from molasses as a source of protein have already been mentioned. That dried yeast is still being produced only experimentally is not for lack of favorable results in experimental feeding trials.

Three double-reversal experiments, the first two of 12 weeks' duration, with 8 cows each, and the third lasting for 15 weeks, with 6 cows, were completed prior to the war. The first trial, although discussed in the 1940 annual report, is included for the sake of completeness in this summary. The complete rations fed in the three tests were quite similar, and an effort was made to balance the principal nutrients. In the first trial, yeast replaced all of the soybean- and coconut-oil meals pound for pound; in the second, yeast replaced all of the soybean-oil meal pound for pound; and in the third, 25 pounds of yeast replaced 6 pounds of coconut- and 20.5 pounds of soybean-oil meals. The rations with their chemical analyses are shown in table 6.

Table 6.—Composition and chemical analyses of rations fed in three double-reversal experiments

Feeds	First trial		Second trial		Third trial	
	Control ration	Yeast ration	Control ration	Yeast ration	Control ration	Yeast ration
Composition:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Cane molasses	25.0	25.0	25.0	25.0	25.0	25.0
Pineapple bran	38.0	38.0	35.5	32.0	38.0	38.0
Coconut-oil meal	10.0		7.0	8.5	10.0	4.0
Soybean-oil meal	25.0		27.5		25.0	4.5
Molasses dried yeast		35.0		27.5		25.0
Copra[1]			3.0	5.0		1.5
Salt	1.0	1.0	1.0	1.0	1.0	1.0
Steamed bonemeal	1.0	1.0	1.0	1.0	1.0	1.0
Analyses:[2]						
Moisture	20.91	20.23	18.86	17.80	16.04	15.31
Protein	14.97	16.40	13.59	14.04	15.07	13.14
Fat	2.56	0.78	3.21	3.70	1.33	1.64
Fiber	11.54	10.00	10.46	8.58	9.81	10.37
Ash	7.47	10.45	9.27	11.40	9.01	10.27
Nitrogen-free extract	41.88	42.16	44.63	44.48	48.74	48.98

[1] Added to increase fat content of ration.

[2] Air-dry basis as fed.

Results of the experiment are summarized in table 7.

Table 7.—Milk production, percentages of fat in milk, feed consumption, and weights of cows in molasses-yeast trials

Concentrate ration	Average daily milk production	Fat content of milk	Average daily milk production (4-percent-fat-corrected)	Average concentrates consumed daily	Average green Napier grass consumed daily	Average live weight of cows
	Pounds	*Percent*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Control						
Trial 1....	23.29	3.48	21.47	18.96	62.2	1,059
Trial 2....	25.82	4.11	26.23	17.01	46.7	1,025
Trial 3....	26.30	3.22	23.12	18.10	42.9	1,120
Average.....	*25.14*	*3.60*	*23.61*	*18.02*	*50.6*	*1,068*
Molasses yeast						
Trial 1....	20.13	3.58	18.85	18.59	67.5	1,063
Trial 2....	21.96	4.42	23.33	17.02	47.5	1,018
Trial 3....	26.2	3.47	24.13	18.10	42.9	1,112
Average.....	*22.76*	*3.82*	*22.10*	*17.90*	*52.6*	*1,064*

The average of the three experiments shows that milk production was somewhat lower when dried yeast was substituted for oil meals. Fat content of milk was higher, however, when yeast was fed, and in the third trial, milk production on a 4-percent-fat-corrected basis was higher for yeast-fed cows. Apparently, yeast, although not a complete substitute for other proteins, may replace them in large part.

The yeast fed in these trials was produced in a small pilot plant operated at the Hawaiian Sugar Planters' Association Experiment Station. *(Henke, Work, Maruyama)*

Protein from Forages

Koa-haole meal. The most promising local leguminous forages, from the standpoint of protein content, are pigeonpeas, koa haole, and desmanthus. In cooperation with the agronomy division, a small quantity of dried meal was prepared from koa-haole tops for experimental feeding to dairy cattle.

Only enough koa-haole meal for a double-reversal trial employing two animals was available. The experimental ration consisted of the following parts: Koa-haole meal, 72; cane molasses, 26; salt, 1; and steamed bonemeal, 1. The control ration was made up as follows: Soybean meal, 30 percent; pineapple bran, 43; cane molasses, 25; salt and steamed bonemeal, 1 each. The nutritive ratios of the two rations were the same, but since the estimated nutrient content of the koa-haole ration was only 72.7 percent as great as that of the control, more of the koa-haole ration was fed.

While definite conclusions could not be drawn from so limited a test, it was noted that the cows on the control ration produced 18 percent more milk on a 4-percent-fat-corrected basis. However, based upon an arbitrary value of $20 per ton for the koa-haole meal, the feed costs per unit quantity of milk were lower for the experimental ration.

Drying of koa haole might have many advantages, especially where transportation or seasonal irregularities in supplies of green forages are factors. For dairymen with adequate land and irrigation water there are distinct possibilities in growing koa haole as a substitute for imported concentrates. *(Henke, Maruyama)*

Green koa haole. The nutritive value of green koa-haole tops was compared with that of Napier grass in three 12-week double-reversal experiments, with six cows in each of the first two trials, and eight cows in the third. Chemical analyses of the two roughages, as determined from daily sampling during the first trial, are shown in table 8.

Table 8.—Analyses of green koa-haole tops and green Napier grass

Feeds	Dry matter in green feed	Calculated on a water-free basis:					
		Crude protein	Ether extract	Nitrogen-free extract	Crude fiber	Ash	Total nutrients
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Koa-haole tops							
Experiment 1	32.60	18.82	2.10	32.59	39.54	6.96	95.65
Experiment 2	31.94	19.88	2.29	34.64	37.05	6.04	96.82
Experiment 3	33.08	17.79	2.44	36.25	36.60	6.92	96.13
Average	*32.54*	*18.83*	*2.28*	*34.49*	*37.73*	*6.64*	*96.18*
Napier grass							
Experiment 1	19.30	6.95	1.61	39.54	38.18	13.72	88.26
Experiment 2	25.48	3.74	1.44	42.85	41.74	10.23	91.57
Experiment 3	22.20	4.06	1.59	39.22	43.36	11.77	90.22
Average	*22.33*	*4.92*	*1.55*	*40.54*	*41.09*	*11.91*	*90.04*

On a water-free basis, the koa-haole tops had about four times as much total protein as the Napier grass. This difference would be even greater on the green basis, as fed, since koa haole contains more dry matter than Napier grass.

In the first experiment both roughages were supplemented by a concentrate ration consisting of the following parts: Cane molasses, 25; pineapple bran, 38; coconut-oil meal, 10; soybean-oil meal, 25; salt, 1; and steamed bonemeal, 1. However, since the chemical analyses of the roughages indicated that an excess of protein had been fed with the koa-haole ration, the protein supplements were entirely eliminated from the concentrates fed with koa haole in trials 2 and 3.

Production, consumption, and cost data are summarized in table 9.

Table 9.—Milk and fat production, live weights, feed consumption, and feed costs in experiments comparing green koa-haole tops and green Napier grass

Roughage	Average daily milk production	Fat content of milk	Average daily milk (4-percent-fat corrected)	Average live weights	Feed consumption				Feed cost[1] per 100 pounds of 4-percent-fat-corrected milk
					Green roughage	Concentrate ration F	Cane molasses	Pineapple bran	
	Pounds	*Percent*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Dollars*
Green koa-haole tops:									
Experiment 1	27.67	3.40	25.17	1,169	48.33	18.34			1.79
Experiment 2	26.28	3.54	24.46	1,169	56.89		5.00	9.00	1.16
Experiment 3	20.23	3.95	20.22	948	52.79		4.82	6.61	1.22
Average of 2 and 3	*23.25*	*3.74*	*22.34*	*1,058*	*54.84*		*4.91*	*7.80*	*1.19*
Green Napier grass:									
Experiment 1	25.82	3.29	23.08	1,183	57.00	17.38			1.63
Experiment 2	25.47	3.61	23.99	1,164	56.43	16.78			1.52
Experiment 3	23.04	3.86	22.39	982	52.34	15.45			1.51
Average of 2 and 3	*24.25*	*3.73*	*23.19*	*1,073*	*54.38*	*16.11*			*1.51*

[1] Cost per ton of concentrates, January 1942, and of roughage: Cane molasses, $7.50; pineapple bran, $21.00; coconut-oil meal, $36.00; soybean-oil meal, $79.00; salt, $25.00; steamed bonemeal, $63.00; Napier grass, $3.00 (assumed; no standard commercial price); green koa-haole tops, $6.00 (assumed).

As an average of the last two trials, when only cane molasses and pineapple bran supplemented koa-haole roughage, milk production was 3.8 percent lower than when Napier grass and high-protein supplements were fed; however, feed costs per quart of milk produced were 27 percent lower at prices obtaining at the time.

It should be noted that on the koa-haole, molasses, and pineapple-bran ration, 96 percent of the protein and 55 percent of the total nutrients were supplied by the green koa-haole tops; when the Napier-grass ration was fed, only 13 percent of the protein and 42 percent of the total nutrients were derived from the roughage.

The possibility of producing milk without imported protein supplements, if koa haole can be economically grown and harvested, is suggested by these results. *(Henke, Work, Maruyama)*

Grazing on koa haole. The effects on milk production of grazing cows on koa-haole pastures and reducing the protein supplements were observed in two 4-week trials. During the grazing periods, a concentrate ration was

fed that contained only 5.43 percent digestible crude protein and 63.41 percent digestible total nutrients. During the 2 weeks preceding and the 2 weeks following the grazing trials, Napier grass was fed as a roughage and the proportion of soybean-oil meal in the concentrate ration was increased. This more expensive concentrate contained 10.88 percent digestible crude protein and 66.49 percent digestible total nutrients.

In the first trial, 17 cows produced 16.7 pounds milk daily while grazing on koa haole, and 17.2 pounds when fed nonleguminous roughages with additional soybean meal. The fact that most of the cows in this first trial were far advanced in their lactation caused a low average production.

In the second trial, 18 cows gave an average daily production of 23.3 pounds while grazing on koa haole, and 22.7 pounds during the 2 preceding and 2 following weeks.

The tremendous value of koa haole, both as a soilage crop and as a pasture plant, is apparent from these results. Even if imported proteins could be assured, the extensive planting of this legume would seem justified.

The agronomic work with this plant is also of considerable significance and should be considered in relation to these findings (see p. 76). *(Henke, Work, Maruyama)*

Green Desmanthus virgatus. Desmanthus is a hardy, shrubby legume which may have promise as a soilage and grazing crop and as a source of protein. Two 12-week, double-reversal trials, each with four cows, have been conducted to determine the value of this legume in milk production. Condensed results are shown in table 10.

Table 10.—Milk production, percentage of fat in milk, feed consumption, and weights of cows in trials comparing *Desmanthus virgatus* and Napier grass

Roughage	Average daily milk production	Fat content of milk	Average daily milk production (4-percent-fat-corrected)	Average concentrates consumed daily	Average green roughage consumed daily	Average live weight of cows
	Pounds	*Percent*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Napier grass						
Trial 1	29.14	3.36	26.36	18.37	47.68	1,111
Trial 2	24.07	3.57	22.53	15.75	69.50	1,241
Average	*26.60*	*3.47*	*24.44*	*17.12*	*58.59*	*1,176*
Desmanthus virgatus						
Trial 1	30.42	3.39	27.62	18.39	35.94	1,105
Trial 2	24.86	3.50	22.999	16.19	55.29	1,205
Average	*27.64*	*3.44*	*25.30*	*17.29*	*45.61*	*1,155*

Samples of the roughages fed daily were secured for moisture determinations, and composites of these samples were analyzed for nutrient content. Average data for both trials are given in table 11.

Table 11.—Analyses of *Desmanthus virgatus* and Napier grass roughages

Roughage	Dry matter in green feed	Calculated on a water-free basis:					
		Crude protein	Ether extract	Nitrogen-free extract	Crude fiber	Ash	Total nutrients
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Napier grass	23.21	4.47	1.61	40.89	41.76	11.26	90.74
Desmanthus virgatus	36.07	11.47	2.14	37.20	43.44	5.75	96.92

Desmanthus virgatus was more than twice as high in protein as Napier grass on the water-free basis, and would be proportionately higher on the green basis.

In these trials the same concentrate ration was fed with both roughages. The data would indicate, however, that an excess of protein was fed in conjunction with the desmanthus. While not so high in protein as koa haole, this legume should give dairymen lower concentrate costs than Napier grass. *(Henke, Work, Maruyama)*

Strip Cane as a Roughage for Dairy Cows

The possibilities of strip cane as a roughage for beef cattle have been discussed (p. 11). They are as great or greater for dairy cattle. In conjunction with koa haole or desmanthus, strip cane might advantageously make up forage requirements. Its general use will doubtless increase as efforts continue to improve the quality, palatability, and nutritive content.

A relatively high quality strip cane received from the mill was compared with green Napier grass in a 12-week, double-reversal feeding trial with eight dairy cows. The same concentrates were fed with both roughages. Live weights of the cows averaged 1,141 pounds when the strip cane was fed, and 1,145 pounds when Napier grass was fed. Average daily milk production (4-percent-fat-corrected) was 24.97 pounds on strip cane, and 25.96 pounds on Napier grass. These differences in live weights and milk production were not significant under the conditions of the test. Consumption of the strip cane was low—only 23.51 pounds per cow per day, as compared with 61.16 pounds of Napier grass.

Daily samples of the roughages were taken for chemical analyses. Results are shown in table 12.

Table 12.—Analyses of strip cane and Napier grass

Feed	Dry matter in green feed	Calculated on a water-free basis:					
		Crude protein	Ether extract	Nitrogen-free extract	Crude fiber	Ash	Total nutrients
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Napier grass	21.69	5.86	1.80	38.06	41.61	12.28	89.58
Strip cane	45.73	3.41	1.07	44.44	44.28	6.80	94.54

The difference in roughage intake was not great when actual dry-matter and nutrient intakes are compared. Daily dry-matter intake from roughage averaged 13.33 pounds when Napier grass was fed, and 10.33 pounds when strip cane was fed.

The results of this one trial indicate that good-quality strip cane is a satisfactory substitute for Napier grass. The cost of roughage per unit of production would doubtless favor the strip cane where transportation is not an expense factor. *(Henke, Work, Maruyama)*

Fat in the Dairy Ration

In a ration compounded largely from local products (pineapple bran, yeast, urea, etc.), the fat content may be very low. Two double-reversal experiments were conducted to determine whether this deficiency in the ration seriously affects milk production and fat content of milk. Results indicated that milk production was not affected, although butterfat was.

The differences in fat content of the experimental rations, however, were not great. In one trial the percentages of fat were 4.18 and 3.19; in the other, 3.36 and 2.13. For a short period, some time after these trials, the only protein supplement available was soybean-oil meal that contained only 0.5 percent fat instead of the usual 4 percent. A reduction in milk production of the entire herd resulted. Although this latter observation was not based on a controlled experiment, it seems probable that the reduction was occasioned by the low fat content of the concentrate ration. *(Henke, Work)*

SWINE

The swine industry in Hawaii, under pre-war conditions, usually provided nearly half of the pork consumed locally. In general hogs are produced much more intensively in the Territory than on the Mainland, and the various problems of feeding, management, and disease are correspondingly increased. The advent of the war, with its resulting shipping problems, has increased the importance of hog production as a local source of meat. Fortunately, the hog is prolific and can make better use of many

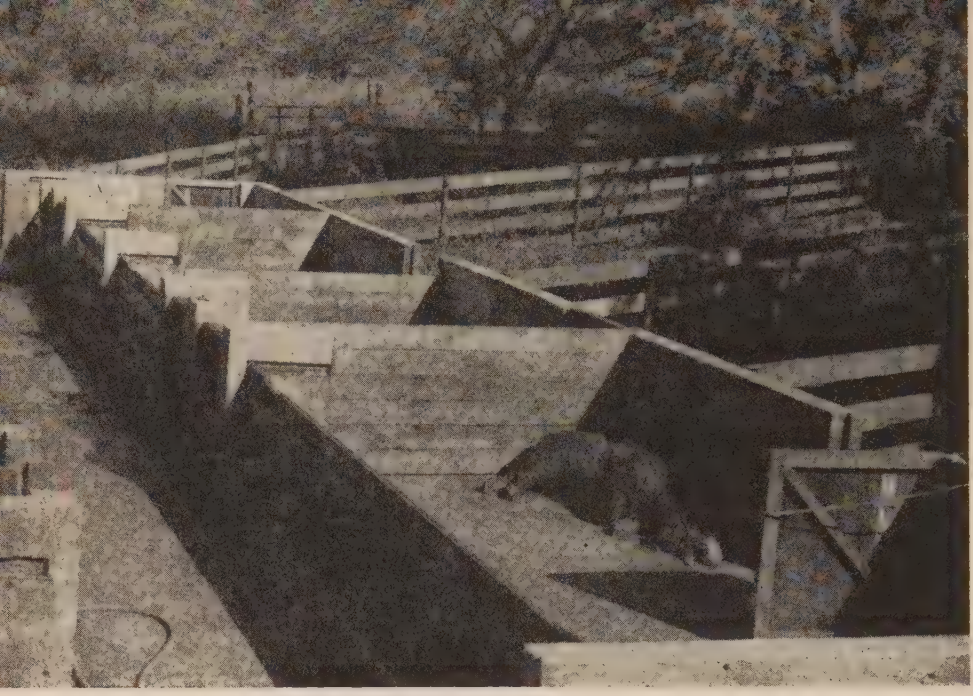


Figure 1.—View of new piggery built at University of Hawaii farm.

waste products than can other classes of livestock. The most serious problem in rapid hog production is to secure an adequate source of protein to supplement the carbohydrate feeds available in Hawaii. The possibilities for wartime expansion of the swine industry seem great if suitable, well balanced rations can be found. The report of the following experiments, designed to solve the problems of swine production, are partial solutions of this wartime feed problem.

Rate of Feeding

When imported feeds are difficult to secure, it becomes important to achieve maximum utilization of the limited quantities available. Much work has been done with laboratory animals that indicates the feasibility of limiting the feed intake during a part of the growing period. An experiment was set up to determine the economy of gain attained by using such a method.

In a test involving two lots, each of eight pigs averaging 44 pounds initial weight, animals that were limited in feed to three-fourths of the daily allowance during the first 91 days and then full-fed the last 36 days averaged 1.04 pounds daily gain. They consumed 4.84 pounds of feed for each pound of gain. Pigs that were full-fed throughout the period averaged 1.15 pounds gain per day and consumed 5.20 pounds feed for each pound of gain. This marked saving in feed was due to the higher efficiency of feed during

the first 91 days of the test (4.12 versus 4.7 pounds feed per pound gain). *(Harris, Work)*

Protein in the Ration of Lactating Sows

A direct effect is known to exist between the weaning weight of pigs and the time it takes for them to reach the market as fat hogs. Furthermore, it is recognized among swine men that, under a given set of conditions, the sow that produces the most milk weans the heaviest pigs. Carrying over to swine the principles of the physiology of lactation learned from dairy cows, there seems every reason to believe that the amount and quality of protein in the ration of the sow would influence the quantity of milk a sow produces and the resulting weight of the weaned pigs. The literature of swine nutrition has many experiments on growing and fattening pigs, but knowledge of the nutritive needs of sows that are suckling pigs is rather limited. In an attempt to gain an insight into these needs, this station has been feeding two levels of protein to sows during the suckling period.

The rations used in this test were composed of corn meal, standard middlings, crushed oats, soybean-oil meal, tuna-fish meal, and green koa haole (in place of alfalfa). Analyses of the rations are presented in table 13.

Table 13.—Analyses of rations for lactating sows

Ration	Dry matter	Calculated on the oven-dry basis:				
		Crude protein	Ether extract	Crude fiber	Nitrogen-free extract	Total ash
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Low-protein	87.68	12.74	1.68	5.56	76.87	3.15
High-protein	86.55	17.46	2.55	3.41	73.63	2.95

The rate of feeding each ration was in proportion to live weight, in accordance with the practice usually recommended for suckling sows.

Actual milk yields, calculated from differences in weight of the pigs before and after nursing, have been secured from six sows that were fed the low-protein mixture. When four of these sows were fed the high-protein mixture at another farrowing, similar data were obtained. Blackout restrictions since December 7, 1941 have limited the studies to 12-hour daylight intervals. Therefore all data on milk production secured before December 7 have been reduced to the same 12-hour basis. The interval between sucklings was established at 2 hours. In the following table these data are assembled. The milk production shown represents the 12-hour yield recorded on one day at the end of each week.

Table 14.—Average milk yield of sows on low- and high-protein rations

Ration fed	Average pigs per farrowing	Milk yield for 12-hour period recorded on one day at end of each week after farrowing							
		1	2	3	4	5	6	7	8
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
High-protein	7.2	3.90	4.04	3.99	3.73	3.31	2.95	[1]2.41	[1]1.80
Low-protein	7.0	3.68	3.29	3.15	2.75	3.23	2.16	2.44	1.79
Low-protein	7.5	2.58	2.85	3.32	3.74	3.20	3.45	2.62	1.19

[1] One sow had a severe attack of hemorrhagic enteritis during these weeks, and her production was so severely affected that data are presented on three sows only.

Average yields of the four sows that were fed on both rations show little difference at the end of the first week when the animals are calling on their own reserves. The yields do widen with advancing lactation, however, and then tend to approximate each other toward the end of lactation. In this respect there is no reason to doubt the application of the same physiological phenomenon of milk production as found with dairy cows, namely, that superior rations prevent too rapid depletion of body reserves and the resulting rapid declines in yield.

In parallel studies of twenty farrowings, the heaviest pigs were most frequently obtained from sows fed the high-protein mixture. Fifty-nine pigs weaned from sows fed the low-protein mixture averaged only 22.9 pounds at weaning time (56 days), whereas 58 pigs weaned from sows fed the high-protein mixture averaged 30.9 pounds.

Sows fed the low-protein mixture lost on the average 25 pounds more weight than sows fed the high-protein ration during the suckling period. Most rapid loss occurred in the first few weeks after farrowing. *(Work, Harris, Maruyama)*

Yeast as a preventive of enteritis. Enteritis is a disease all too common wherever pigs are raised. Many investigations into its cause have been conducted at various mainland stations. The 1941 Yearbook of Agriculture, issued by the United States Department of Agriculture, lists a pathogenic organism as the chief agent.

In the course of an investigation already reported (1940 annual report), the observation was made that the pigs fed dried yeast seemed healthier and recovered more quickly from a diarrhea than those fed fish meal. On the theory that a vitamin deficiency might weaken the pigs to such extent that they would become susceptible to the pathogenic organism, this station has been fortifying the diets of pigs, from weaning to the time they are 80 pounds in weight, with dried cane-molasses yeast. Although no positive results have been obtained to date, it can be said that this yeast, fed at the rate of 2 ounces per pig per day, seems to aid in the prevention of enteritis, provided feed and water troughs, and the quarters in general, are kept in a sanitary condition. *(Maruyama, Work)*

Feeding of Local Byproducts

Cane molasses for weanling pigs. Shotes properly cared for from weaning up to the time they are about 80 pounds in weight are then able to go into the feed lot and do well. The problem is to find adequate, cheap rations to be fed during this early critical period. Cane molasses is the cheapest constituent of any ration in Hawaii, but it is known to cause diarrhea when fed in excess. Therefore this station has been interested in ascertaining how much molasses could be fed to weanling pigs and also whether, in spite of its cost, raw sugar was any better than the molasses.

In a preliminary test, two lots of pigs were fed rations identical in composition except that 10 percent cane molasses in one ration was replaced with the same amount of raw sugar in the second ration. Other percentages of feeds in each ration were: Barley, 48; middlings, 20; tankage, 15; soybean-oil meal, 5; and salt and steamed bonemeal, 1 each. On the oven-dry basis the sugar ration contained 21.26 percent protein, 2.26 percent fat, 4.27 percent fiber, 62.38 percent nitrogen-free extract, and 9.83 percent ash. The molasses mixture contained 21.28 percent protein, 2.39 percent fat, 4.54 percent fiber, 60.28 percent nitrogen-free extract, and 11.51 percent ash.

Tests involving 13 weanling pigs are summarized in the following table.

Table 15.—Gains in weight and feed consumption of weanling pigs receiving molasses and raw-sugar rations

Ration	Total number of pigs	Days on feed	Average initial weight	Average daily gain	Daily feed per pig		Feed per 100 pounds of gain
					Concentrate	Green koa haole	
			Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Sugar	7	47	37.5	0.83	3.54	1.00	4.40
Molasses	6	47	37.1	0.88	3.91	1.00	4.43

No ill effects resulted from the feeding of 10 percent cane molasses to these weanling pigs. The study is being continued. *(Work, Henke, Maruyama)*

Pineapple sirup. In this station's annual report for 1940, the effects of feeding pigs rations containing up to 50 percent of pineapple sirup were discussed. (Pineapple sirup is the residue of waste pineapple juice after extraction of the citric acid. Though somewhat like molasses in appearance, it weighs less per gallon.) In continuation of this work, the percentage of pineapple sirup in the experimental ration was increased to 80. The remaining 20 percent of the ration, a protein supplement, consisted of 49 parts soybean-oil meal, 49 parts tuna-fish meal, and 1 part each of salt and bonemeal.

Twenty pigs averaging 64 pounds were placed in two lots. Lot 1 was full-hand-fed the experimental ration for 49 days. They were then full-hand-fed to market weight a ration consisting of 68 pounds rolled barley, 20 pounds cane molasses, 5 pounds local tuna-fish meal, 5 pounds soybean-oil meal, and 1 pound each of salt and bonemeal. Lot 2 followed the reverse procedure, being started on the check mixture and changed to the pineapple-sirup ration at the end of 49 days.

At the end of the first period the pigs in lot 1 had reached an average weight of 106 pounds, representing a daily gain of 0.87 pound, and had consumed 5.13 pounds of feed for each pound of gain. At the same time the check lot had consumed 4.02 pounds mixture per pound of gain, with the pigs averaging 122 pounds, for a daily gain of 1.18 pounds.

Following the change, the pigs in lot 2, now on pineapple sirup, gained 1.89 pounds a day, consuming 6.23 pounds of feed per pound of gain. These pigs reached 188 pounds in 35 days, two weeks earlier than the other lot. The pigs in lot 1 averaged 1.47 pounds a day gain on the check mixture, consuming 4.5 pounds feed per pound of gain. These pigs took 49 days to reach market weight.

On the whole, it seems desirable to start feeder pigs on a reasonably good mixture, such as the check here used; then when they have reached 100 to 120 pounds in weight, they may be finished for market on the considerably less expensive pineapple-sirup mixture. The pigs handled in this way gained 1.48 pounds daily, as compared to 1.17 for those fed the sirup mixture during the first part of the fattening period.

An analysis of pineapple sirup as submitted by Dr. E. F. Cornell of the Hawaiian Pineapple Company, Ltd., gives the following percentages: Dry matter, 76.3; crude protein, 2.1; ether extract, 1.6; total ash, 2.3; and nitrogen-free extract, 70. *(Work, Henke, Maruyama)*

Cull tomatoes. Hawaii's diversification-of-crops program results in an availability of surpluses and culls of certain fruits and vegetables.

In order to ascertain the value of whole cull tomatoes, experimental lots of pigs were fed on tomatoes only, on different proportions of tomatoes and concentrates, and on concentrates plus fresh green feed.

The concentrate mixture was made up of the following parts: Rolled barley, 64; cane molasses, 20; local tuna-fish meal, 7; soybean-oil meal, 7; and salt and bonemeal, 1 each. It was estimated to supply 10.11 percent digestible crude protein and 71.2 percent total digestible nutrients.

Twice weekly, samples of the whole cull tomatoes were obtained, dried, and composited. The average analysis of four, 4-week composites on the fresh basis showed 5.54 percent dry matter, 1.23 percent crude protein, 0.22

percent ether extract, 0.73 percent crude fiber, 2.76 percent nitrogen-free extract, and 0.64 percent total ash.

In the first test, 32 pigs, averaging 75 pounds, were fed for 22 days; in the second test, 17 pigs, averaging 117 pounds, were fed for 45 days. The results in terms of the replacement value of the tomatoes for the barley-molasses concentrate mixture are as follows:

In 75-pound pigs, tomatoes alone produced no gain. When 2.37 pounds of concentrate mixture and 12.52 pounds of tomatoes were fed daily, the gain was 0.75 pound per day, and the tomatoes were worth 5.56 percent of the mixture they in part replaced. With 3.66 pounds of mixture and 8.47 pounds of tomatoes, the gain was 1.13 pounds per day, and a replacement value of 11.7 percent was obtained. The pigs consuming no tomatoes ate 4.92 pounds of the concentrate daily to gain 1.20 pounds.

For the 117-pound pigs it was necessary at times to feed a certain small amount of concentrate mixture because no tomatoes were available. Therefore, only the results of three levels of concentrate feeding are available.

The 117-pound pigs that were fed 0.76 pound of concentrate mixture and 48.77 pounds tomatoes per day gained 0.66 pound daily. In this case the replacement value of tomatoes was 4.44 percent. The pigs fed daily 2.69 pounds concentrate mixture plus 33.79 pounds tomatoes gained 1.42 pounds per day. In this case the tomatoes had a replacement value of 10.4 percent. Similarly, a daily intake of 4.66 pounds of concentrate and 27.69 pounds of tomatoes produced 1.81 pounds daily gain, with a replacement value of 11.7 percent for the tomatoes. The pigs that were fed only the concentrate consumed 7.72 pounds daily to gain 1.77 pounds.

In general, these results show that although tomatoes alone are unsatisfactory as a hog feed, in combination with a good concentrate ration they have a value ranging from 4 to 12 percent of the value of the concentrate mixture which they in part replace, the greater percentage value resulting when less of the tomatoes is fed. *(Work, Henke, Maruyama)*

Taro. In experiment 2 of this series, two lots of 9 pigs each, averaging 87 pounds, were fed for 65 days. Lot 1 was full-hand-fed three times daily all they would eat of whole, unpeeled cooked taro and had free access to a protein supplement, consisting of 49 pounds tuna-fish meal, 49 pounds soybean-oil meal, and 1 pound each of salt and bonemeal. Lot 2 was fed the concentrate mixture previously described in the section on cull tomatoes. Fresh green feed was provided daily for each lot.

The pigs in lot 1 consumed daily 20.84 pounds of cooked taro and 1.13 pounds of protein supplement, and gained 1.09 pounds a day. The pigs in lot 2 ate 6.32 pounds of the check mixture per day, and gained 1.38 pounds a day. Thus the taro ration produced 80 percent as much gain as the check

mixture, duplicating the results of experiment 1 (1940 annual report). The fact that the taro-fed lot gained less is probably due to the failure of the pigs to eat enough protein supplement to balance the ration.

Cooked taro has the following analysis: 38.41 percent dry matter, 1.18 percent crude protein, 0.17 percent ether extract, 0.37 percent crude fiber, 36.69 percent nitrogen-free extract, and 0.59 percent ash. *(Work, Henke, Maruyama)*

Garbage for Swine

Many pigs in Hawaii, particularly those around the larger towns and cities, are fattened exclusively on garbage, and swine producers have often paid high prices for the privilege of obtaining such wastes.

One experiment tested the value of garbage obtained from the University cafeteria. Because the amount of garbage was limited, only two trials, employing 14 pigs, could be undertaken.

In one trial, eight 87-pound pigs were fed for 86 days. One lot of four pigs received a concentrate mixture composed of 64 pounds rolled barley, 20 pounds cane molasses, 7 pounds tuna-fish meal, 7 pounds local meat- and-bone meal, and 1 pound each of salt and bonemeal. The mixture was hand-fed twice daily to the limit of appetite.

The four garbage-fed pigs were given approximately one-third of the amount of concentrate consumed by the check group, but in addition they had access to all the raw University cafeteria garbage they would consume.

In another trial, three pigs in each of two lots were similarly fed for 49 days.

Data on both these trials are summarized in the following table:

Table 16.—Feed consumption and weight gains of swine in garbage-fattening trial

Number of pigs	Ration fed	Initial weight	Average daily gain	Daily feed consumed			Feed consumed per 100-pound gain		Concentrates replaced by 100 pounds garbage
				Concentrate	Garbage	Greens	Concentrate	Garbage	
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
4	Check	87.6	1.36	6.91	.....	1.00	508.09	.....	.....
4	Check plus garbage	87.4	1.45	2.21	15.62	1.00	152.4	1,077.4	33.02
3	Check	132.2	1.19	7.09	.....	1.00	596.6	.....	.....
3	Check plus garbage	132.5	1.50	2.98	14.7	1.00	196.7	980.0	40.57

For both trials, the concentrate mixture contained 84.2 percent dry matter, which, on an oven-dry basis, analyzed 16.14 percent total protein, 1.98 percent fat, 5.00 percent fiber, 9.85 percent total ash, and 67.03 percent nitrogen-free extract. The garbage contained 27.27 percent dry matter, analyzing, on the oven-dry basis, 13.18 percent total protein, 34.01 percent fat, 3.88 percent fiber, 2.55 percent ash, and 46.38 percent nitrogen-free extract.

The nutrition laboratory is running vitamin assays on the pork obtained from pigs fed each of these rations. *(Work, Henke, Maruyama)*

WORK ANIMALS

Feeding Liquid Yeast

When dried yeast is made from cane molasses, the slurry, which contains about 83 percent water and 6.9 percent protein, is evaporated to dryness. To economize on fuel costs, attempts were made to determine whether the yeast slurry itself would be a satisfactory source of protein in the rations of cattle and work animals.

Viable yeast made from cane molasses was fed to one mule for 276 days, average daily intake of the wet yeast being 2.10 pounds. This mule maintained his weight throughout the entire period and apparently was in good health.

The same yeast slurry was fed to a mare for 152 days, the average daily intake being 5.20 pounds. Although the mare consumed this larger quantity of wet yeast slurry fairly well (as high as 7.36 pounds daily during the fourth month), she went off feed in the fifth month and lost weight.

The slurry was mixed with cane molasses to make it more palatable. Pineapple bran was also included in the ration.

This was merely an observation test to note the effects of feeding viable yeast to work animals. The quantities fed were much too small to supply enough protein for animals doing heavy work. Roughage was supplied by pasturing the animals. *(Work, Henke, Maruyama)*

POULTRY AND RABBITS

The poultry industry of Hawaii, an important source of food to the Territory, is dependent upon mainland feeds to a greater degree than are other animal industries. Immediately after the outbreak of the war, poultrymen were asked to destroy stock not large enough to market and to cull producing flocks heavily in order to conserve feed. Poultry and dairy feeds were immediately rationed. Fortunately, feed supplies were replenished after a few weeks, and the poultry industry was saved from further loss.

The problem of suitable and abundant feeds still remains, however. Unfortunately, urea is of no value as a protein substitute for poultry; this was proved by an experiment report before the war (1940). Local sources of fish meal and bonemeal have largely disappeared since the outbreak of war, as the fishing industry has been severely curtailed. Such supplies as are available are largely reserved for the poultry and swine industries.

However, as with dairy cattle and swine, the experiment station had long before the war foreseen the difficulties that might arise if supplies were interrupted and had directed considerable attention to the practical solution of many of the problems. The results secured have been of great value to the industry itself and to the public.

POULTRY FEEDS

Emergency Poultry Rations

Eight months before the outbreak of war, experiments were begun to determine the value of laying rations composed entirely of locally produced feeds. Some of these rations were of necessity radically different from the usual mixtures, and experiments with six rations had to be dropped when egg production and body weight of pullets receiving them declined rapidly. On the only ration that proved satisfactory, pullets maintained a production greater than 50 percent. This satisfactory ration was made up of the following ingredients:

	Parts
Red Milo maize	40
Cane-molasses yeast	15
Koa-haole-seed meal	5
Cracked Kohala corn or finely ground pineapple bran	15
Pigeonpea meal	5
Algaroba-bean meal	15
Local meat-and-bone meal	5
Salt	1
Coral sand	2

Honohono grass, sweetpotato vines, pigeonpea or koa-haole leaves—1 pound per 20 hens daily

This ration is composed entirely of feeds that are produced or may be obtained locally, but to produce them in adequate quantities would require careful planning and coordination. The plant for producing yeast (see also p. 19) has not yet been built, and to produce the maize, pigeonpea meal, and koa-haole-seed meal would require assignment of cultivated acres for this purpose.

Figure 2.—Breeding stock, 1 year of age, of small-type turkeys at the University of Hawaii poultry farm.

Local Protein Sources

Tuna-fish meal. It was not foreseen that the fishing industry, which formerly supplied very considerable quantities of feeds as well as human food, would be curtailed because of the war. Steps are now being taken to find substitutes for these feeds.

Before the war had curtailed the supply, experiments had been undertaken to demonstrate the value of fish meal in poultry feeding because of its local availability. Tests in which the local, flame-dried fish meal was substituted for imported fish meals and bonemeals in the ration for chicks and laying hens have demonstrated that the local product is equal to imported fish meals in every way. No differences were observed in rate of growth, feather growth, mortality, or egg production. No detrimental effects were noted in flavor of flesh or in flavor and quality of the eggs produced.

Cane Molasses

Yeast. Like dairy cattle, poultry require large quantities of protein-rich feeds for maximum production. But unlike cattle, poultry are unable to utilize nitrogen from urea, nor are the plant proteins from legumes, because of their high fiber content, completely satisfactory. Fish and meat scraps and yeast seem to be the only other possibilities. Yeast produced in an experimental plant by the Experiment Station of the Hawaiian Sugar Planters' Association has been tested in an experiment involving 6 lots of at least 25 New Hampshire chicks each. The yeast was substituted for meat scrap, and/or fish meal, and/or soybean meal in various proportions up to 25 percent of the chick rations. Males were carried through 10 weeks, and females through 16 weeks. This preliminary test indicated that chicks can maintain growth on rations in which yeast replaces imported protein concentrates, and that the product would be a desirable addition to local emergency feeds. The extent to which it can most advantageously replace imported proteins in normal times is yet to be determined.

Three lots of 20 pullets each were then placed on laying rations. One lot received a ration that contained about 17 percent yeast. The test has been in progress 5 months, and no reduction in egg production has yet resulted from the feeding of cane-molasses yeast.

Pollen. The bee industry of the Territory offers a rather unusual source of protein. The pollen gathered by the bees in large quantities, particularly during the kiawe or algaroba flowering season, may be screened or brushed off as the bees enter the hive. The entomologist of the local United States Bureau of Entomology laboratory supplied a sufficient quantity of pollen gathered in this manner to conduct a small test.

In the regular chick ration 15 pounds of pollen were substituted for 20 pounds of standard wheat middlings. After 8 weeks it was found that the 25 New Hampshire chicks on the pollen ration were slightly heavier than those on the wheat middlings, indicating that pollen, if made available, might be substituted for the imported feed.

Koa-haole-seed meal. In a 6-week chick-feeding trial 160 pounds of a koa-haole-seed meal were substituted for 100 pounds of peanut meal in the ration. The chicks on the koa-haole ration grew at a normal rate, and the mortality was the same in both groups. Other experiments with koa haole in poultry and rabbit feeding have been less favorable; so the meal should be used with caution unless constituting only a small percentage of the feed for relatively short periods.

Grain Substitutes

Red Milo maize. In 2 experiments, each with 2 lots of 50 New Hampshire chicks, ground Red Milo maize was substituted pound for pound for yellow corn meal in a chick ration containing 30 pounds of the ingredient. Body weights, taken weekly, showed that the chicks receiving the ground Red Milo maize grew at the same rate as those receiving the yellow corn meal. Mortality during the 12-week test in both experiments was nil. In an experiment with laying hens, ground Red Milo maize replaced ground yellow corn in the mash mixture and whole yellow corn as a scratch feed. The feeding trial, which extended over a period of 8 weeks, indicated that hens fed Red Milo maize maintained egg production equal to that of the lot fed yellow corn. *(Bice)*

Taro. Cull taro has been shown in previous reports to have considerable value in animal feeding. The purpose of the study reported here was to determine the feeding value of cull taro as a substitute for scratch grains in poultry feeding. Three groups of 50 week-old New Hampshire chicks were employed in the experiment. Lot 1, which served as the check lot, received two feedings of scratch grains daily; lot 2, cooked cull taro once daily; and

lot 3, cooked cull taro three times daily. Observations made at feeding time showed that the taro was palatable, as it was greedily consumed at each feeding. Taro-fed chicks compared favorably with the check group in body size, vigor, health, and rapidity of feathering. No mortality occurred in the taro-fed lots. The results of the 8-week feeding trial showed that cooked cull taro was a satisfactory feed for growing chicks and that it could displace all of the scratch grains in chick rations. *(Bice)*

POULTRY MANAGEMENT

Poultry-House Design

The design of economical poultry houses for Hawaiian conditions has continued to receive attention. Circular 19 of this station, issued in June 1942, describes and illustrates designs of brooder and laying batteries. Work on economical wire-floored houses has also been continued, with the objective of studying production and general health of the birds.

Two open-air houses have been constructed. In one the roosts are raised slightly above the floor, and protection against wind and rain is provided by placing laths 1½ inches apart at a 45-degree angle around the roosting section. The other house is entirely unprotected, and the roosts are in ladder form. Both are roofed with corrugated iron, and the floors are 1- by 2-inch welded 14-gauge wire fabric (see fig. 3).

Birds in the open house compared favorably in egg production with birds in the more protected house, and they did not contract colds. As a further test, 145 New Hampshire pullets, 9 weeks of age, have been confined in the open house.

Cutting Combs

The general practice in Hawaii is to cut the combs of Single Comb White Leghorn males at 6 months of age. In an experiment with 150 males and females, the combs were removed at 1 day of age. No bleeding resulted from the operation. At 16 weeks of age all birds appeared healthy and nor-

Figure 3.—New open-air type of poultry houses for Hawaii. Pullets in these houses have shown no signs of developing colds, although they are constantly exposed to the weather.

F'gure 4.—A force-draft type of incubator, in which an 80-percent hatch of Muscovy duck eggs has been obtained.

mal, except in growth of comb. Body weight and sexual maturity did not differ from those of chicks whose combs were not cut. It was observed that unless combs were cut close to the skull considerable comb growth resulted. *(Bice)*

Small-Type Turkeys

Hatching eggs of small-type turkeys were imported from the Federal Experimental Farm at Beltsville, Md., in the summer of 1941. The females from these eggs weighed 8¼ pounds at 7 months of age, when they began laying. Males weighed 16¼ pounds at 7 months. As a foundation for further expansion, this station has disseminated stock, poults, and hatching eggs to turkey breeders in the Territory.

A study is now in progress to determine feed consumption and cost per pound of gain. *(Bice)*

Hatching Muscovy Ducks

For many years Muscovy ducks have been popular in Hawaii as a source of quality meat because they are hardy and relatively easy to raise.

Hatching in incubators has given poor results. Therefore, studies (reported in 1940) in developing a method of artificial incubation that would give results comparable to those obtained with artificial incubation of chicken eggs have been continued.

In one method evolved, which gave 80-percent hatchability of fertile eggs, the temperature was maintained at 98½° to 99° F. during the first 30 days and at 90° from the thirty-first day until the hatch was completed on the thirty-fifth day. Humidity from the first to the thirtieth day was maintained at a point which gave a reading of 85° on the wet bulb; thereafter the wet-bulb reading was 91°. During the 30-day period, warm water was sprinkled over the eggs once a day; from the thirty-first day until hatching, water at 140° to 150° F. was poured once daily into the moisture pans. The eggs were turned every 4 hours throughout the hatch. A force-draft, cabinet-type incubator was used in this experiment. A study of the size of air cell indicated that the embryo filled two-thirds of the egg at hatching time. In table 17 are presented measurements of the air cell on the seventh, fourteenth, twenty-first, twenty-eighth and thirty-first day of incubation.

Table 17.—Air-cell size of Muscovy-duck eggs during the period of incubation

Day	Diameter	Depth
	Inches	*Inches*
7	7/8	3/16
14	1¼	3/8
21	1 7/16	½
28	1⅝	¾
31	1¾	⅞

Poultrymen who hatch Muscovy eggs in incubators may use figure 5 as a guide in determining whether proper humidity conditions have prevailed during the period of incubation. *(Bice)*

POULTRY DISEASES

Diseases are a matter of great importance in an industry as highly specialized as poultry husbandry. Although the station is not equipped to undertake detailed work in this field, certain observations and trials are here reported as a matter of record, even though definite conclusions may not be drawn.

Paralysis

Twenty-seven paralyzed birds were examined during the year. Four of these, on study and at autopsy, were shown not to be paralyzed but incapacitated because of other diseases. Both bilateral and unilateral paralyses were observed, though the latter were more frequent. Fourteen of the birds at autopsy showed enlarged nerves; 13 possessed nerves that appeared normal.

The enlarged nerves showed changes of the nerve fibers but, with one exception, no infiltration of lymphocytes. The disease was, therefore, thought not to be a typical neurolymphomatosis but to resemble more the degeneration of nerves observed in vitamin G deficiency. Five paralyzed birds were injected with vitamin B complex, and all recovered and regained ability to stand and to walk. Three that were killed as soon as they recovered were found to possess enlarged nerves. When injection of the other two was discontinued, one continued to be normal for 60 days and the other for 29 days, but both developed severe paralysis again and did not respond to further injections of vitamin B complex. These two possessed greatly enlarged nerves, the largest nerves observed in the entire study. One of the two also showed extensive infiltrations of lymphocytes, the only bird of the entire group to do so. Only minor pathology of the visceral organs was observed. No explanation of the results obtained by injecting the vitamin B complex can be offered. *(Hamre, McHenry)*

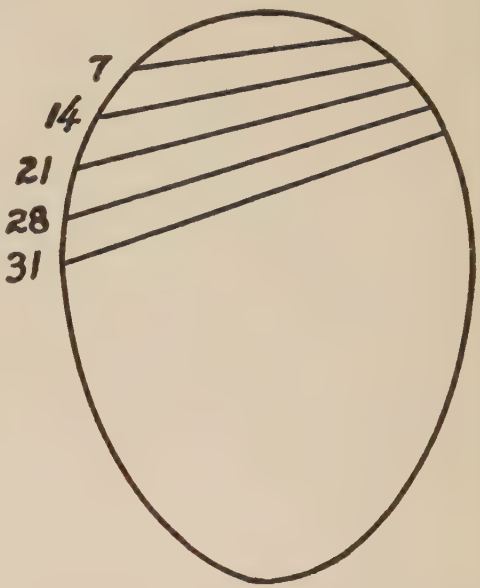


Figure 5.—Air-cell size of Muscovy-duck eggs during the period of incubation. Air cell occupies one third of egg, and the embryo two thirds, on the thirty-first day.

Coccidiosis

During the past 6 years, approximately 20,000 chicks have been brooded at the station poultry farm in wire-floored battery brooders without losses from coccidiosis. Chicks brooded in colony houses, with litter on the floor, suffered losses of from 5 to 40 percent. Commercial poultrymen who have adopted wire-floored battery brooders claim that mortality has been reduced from 25 to 60 percent to 5 to 10 percent. In no instance have they reported deaths due to coccidiosis. *(Bice)*

Fowl Pox

If day-old chicks could be successfully vaccinated against fowl pox, it

would reduce the cost of protecting baby chicks against mosquitoes, which transmit the disease. Moreover, it is easier to vaccinate day-old chicks than the older birds.

Experiments undertaken several years ago (reported in 1940) resulted in high mortality. In a later experiment, 100 day-old chicks were vaccinated in the web of the right wing, 50 with embryo-origin vaccine and 50 with chicken-origin vaccine. There were 4 deaths and 6 culls in the first group, and 7 deaths and 5 culls in the second. Thus in both groups there was a loss of at least 20 percent, a figure too high to justify recommending vaccination of day-old chicks. *(Bice)*

RABBIT FEEDS

Immediately after the war began, the station initiated a special study whose main objective was to promote local production of rabbit meat during the present emergency. To be of value to the present food program, such production should utilize to the greatest possible extent locally produced green feeds and concentrates.

Green Feeds

Pigeonpeas were the only satisfactory single source of green feed. Kikuyu grass was not consumed in sufficient amounts to maintain body weight. Koa haole, when it was the sole source of green feed in the ration, caused rabbits to shed their hair. (When constituting only 10 percent of a green mixture, however, it did not induce shedding.) A silage composed of koa haole and molasses also proved unsatisfactory as a feed for all classes of rabbits. The animals receiving it did not grow normally, the does failed to maintain body weight, and young were dead at birth.

A satisfactory green-feed mixture for all classes of rabbits was composed of the following parts: Pigeonpea leaves and stems, 20; lawn clippings, dry and fresh, 15; Mexican grass, 15; Guinea grass, 10; sweetpotato vines, 10; Napier grass, 10; desmanthus, 10; and koa haole, 10.

Concentrates and Rations

Dried coconut was satisfactory for growing stock, old bucks, and unbred does. When nursing does were fed on the coconut, however, the young did not grow normally, and their hair was rough and oily.

Coarse pineapple bran when fed with algaroba-bean meal and green feed was generally satisfactory. Although some rabbits refused the bran or ate only small quantities, in most instances it was consumed in sufficient amounts to justify its use.

A local ration of pigeonpea leaves and stems, fed with algaroba-bean meal, was satisfactory for all classes of rabbits. At 5 months of age males

Figure 6.—Above: Rabbit fed fresh koa haole as sole green feed. Note loss of hair, which koa haole appears to cause in all non-ruminants. Below: Young rabbit fed ration containing coconut and koa-haole silage. The coconut causes rough, oily hair and sore eyes.

that were fed this ration averaged 6¼ pounds, and females, 5 pounds. *(Bice)*

STUDY OF BLOOD OF CHICKENS

Methods of Obtaining Blood

Before studying the effect of diet on blood values of chickens, an attempt was made to determine the best methods of obtaining blood samples of chickens for the enumeration of the cellular elements and the determination

of cell volume. The direct method of obtaining blood samples was found satisfactory for blood-cell enumeration; it was also satisfactory for cell-volume determination when it was performed with capillary hematocrit pipettes. However, the indirect method gave consistently accurate results for cell volume and it, rather than the direct method, is recommended.

In the indirect method, 0.05 cubic centimeter of a stock heparin solution (prepared by adding 0.75 cubic centimeter Liquaemin to 5 cubic centimeters sterile distilled water) was placed in hypodermic syringes, the syringes were dried to eliminate water, and original blood samples of 1 to 2 cubic centimeters were drawn. A salt solution recommended by the manufacturers for diluting the heparin tended to shrink the erythrocytes of small samples of blood. Subsamples of heparinized blood centrifuged in capillary pipettes or Wintrobe tubes yielded cell volumes consistently similar to each other and to values obtained from samples taken simultaneously by the direct method. The heparinized blood samples were found satisfactory for blood-cell enumeration when the subsamples were taken immediately after the original sample. *(Hamre, McHenry)*

Effect of Diet on Blood Values

No statistically significant differences were found between the blood values of 18 hens fed an adequate laying ration and 21 hens fed the same laying ration supplemented by a yeast-fermented mash. Mean blood values

Figure 7.—Young doe raised on ration composed solely of pigeonpea leaves and stems. The pigeonpea is the only satisfactory single source of green feed for rabbits so far discovered.

for the entire group were therefore determined and presented as normal blood values. Included were values for volume of packed red blood cells and corpuscular constants, the latter being presented for the first time for birds.

The mean normal values obtained were as follows: Hemoglobin, 11.9 grams per 100 cubic centimeters blood; erythrocytes, 2,996,000 per cubic millimeter; thrombocytes, 27,100 per cubic millimeter; volume of packed red blood cells, 29.7 percent; mean corpuscular volume, 99.4 cubic microns; mean corpuscular hemoglobin, 39.8 micromicrograms; mean corpuscular hemoglobin concentration, 40.6 percent; leucocytes, 34,200 per cubic millimeter blood. Differential leucocyte counts gave the following percentages: 30.8 for heterophiles, 4.6 for eosinophiles, 2.7 for basophiles, 60.7 for lymphocytes, and 0.8 for monocytes.

It appears that the great variation in the normal values presented in the literature for lymphocytes and monocytes may be due to lack of agreement about the distinguishing characteristics of the two types of leucocytes and to the fact that cells of all degrees of transition between large lymphocytes and monocytes occur in the blood of birds. *(Hamre, McHenry)*

PARASITOLOGY PROBLEMS

CATTLE PARASITES

Liver Flukes

Drug treatment. In the annual report for 1940 a summary was given of the successful treatment of 29 cattle with a preparation consisting of hexachloroethane and kamala extract (alcoholic). The drug was administered at the rate of one capsule (10 grams of hexachloroethane and 1.75 grams of kamala extract) to each 70 pounds body weight over periods of 2 and 3 days.

Since publication of these data, 28 additional animals have been treated, with consistent results. The degree of fluke infection was determined by the number of fluke eggs present in the feces. In the animals treated for 2 days, where the fluke-egg counts before treatment were less than 35 per gram of feces, the drug reduced the egg count to zero. In other animals, where egg counts ranged from 45 to over 300, the drug reduced egg counts by 88 to 100 percent. The drug was also effective when administered to animals over a 3-day period, although a few animals with egg counts from 4 to 17 still showed slight fluke infections following treatment.

In order to determine whether better results could be secured with a carbon-bisulfide extract of kamala than with the alcoholic extract, 8 additional animals, ranging in weight from 384 to 1,132 pounds, were treated. An equivalent amount of the carbon-bisulfide extract was used in each capsule, and the dosage was at the same rate. Fluke infection in the animals

ranged from 11.9 to 119.0 eggs per gram of feces. Three of the animals were still infected after the treatment, although the egg counts were much reduced. One cow, which had calved about 1½ months prior to treatment, became extremely sick from a single dose of 6 capsules. The symptoms shown were primarily those of shock, weakness, loss of appetite, and lameness or paralysis of the hindquarters. The single dose reduced the egg count in this animal from 45.5 to 11.2 eggs per gram of feces. Another cow in the same herd exhibited a lesser degree of lameness in the hindquarters following the second treatment. Because of the toxicity, and because this combination of drugs did not indicate greater efficacy, the tests were discontinued.

It may be concluded that hexachloroethane and kamala extract (usually obtained commercially as an alcoholic extract) is a safe, efficient, and economical drug for the treatment of cattle for liver flukes, at the rate of one capsule (10 grams hexachloroethane and 1.75 grams kamala extract) to 70 pounds body weight. The drug appears to be slightly more effective when given over a 2-day period, but it is suggested that animals in poor condition or showing reduced vitality be treated over 3 days. *(Alicata, Cuckler)*

Transmission. Previous reports on the susceptibility of fresh-water snails to the liver fluke, *Fasciola gigantica,* have dealt with six species commonly found on low land, of which only one, *Fossaria ollula,* is a suitable intermediate host.

A seventh species, *Succinea caduca,* was collected near Ewa, Oahu, in a stream at an altitude of about 400 feet, and the snails were exposed to infection with the fluke miracidium. No evidence of infection was found in these snails when they were examined from a few days to a month later. *(Alicata)*

Filaria Worm

Life history. Stephanofilaria stilesi, a nematode commonly causing skin lesions, has a wide geographical distribution throughout the United States and also occurs locally. A related species from cattle in Dutch East Indies has been reported.

The lesions produced by the worms are principally on the midventral line of the abdomen in the region of the navel. The lesion is characteristically a hairless, thickened, blood- and dirt-encrusted, scabby patch of skin, ranging in size from a small spot to areas as large as 4 inches wide by 15 inches long.

Histological sections of the skin from these lesions showed small embryos enclosed in a vitelline membrane. These embryos are similar in appearance to those occurring in the uteri of the adult female worms, and it seems probable that they are the infective stage for some arthropod vector, most likely a blood-sucking insect, which in turn transmits the parasite to uninfected cattle.

The only important, abundant blood-sucking insects feeding on local cattle are the stable fly, *Stomoxys calcitrans,* the horn fly, *Haemotobia irritans,* and various species of mosquitoes. The house fly, *Musca domestica,* is not a blood-sucking species although it will feed on open wounds on cattle.

Many attempts were made in the laboratory to determine what insect might be responsible for the transmission of these nematodes to local cattle, but only negative results were obtained. *(Cuckler, Alicata)*

Parasite Surveys

Cattle. A survey was initiated on animal parasites, other than liver flukes, occurring in local cattle. Examinations were made of the skin and viscera of animals killed at one of the Honolulu slaughterhouses, chiefly mature range cattle or old dairy cows. Nearly all of the animals were from the Islands of Hawaii and Oahu, and only a few from Maui, Molokai, and Niihau. The following table summarizes the results of the examinations, giving the name of the parasite, the source, and the number of cattle in which each parasite was found.

Table 18.—Summary of parasites found in Hawaiian cattle

Parasites	Hawaii		Oahu		Maui		Molokai		Niihau		Totals			
	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative	Examined	Percentage of infection
Of the digestive tract:														
Gongylonema pulchrum	163	77	29	71	10	10	0	5	0	7	202	170	372	54.3
Haemonchus contortus	1	124	1	58	0	20	0	0	0	7	2	209	211	.9
Bunostomum phlebotomum	18	222	7	93	0	20	0	5	0	7	25	347	372	6.7
Cooperia punctata	11	254	1	79	0	20	0	5	3	4	15	362	377	4.0
Cooperia pectinata	0	265	1	79	0	20	0	0	0	7	1	371	372	.3
Of the skin:														
Stephanofilaria stilesi	175	6	72	18	20	0	5	0	0	7	272	31	303	89.8
Hypoderma lineatum	79	102	0	90	0	20	0	5	0	7	79	224	303	26.1
Otobius megnini	114	116	31	69	15	5	0	0	0	7	160	197	357	44.8
Haematopinus eurysternus	1	259	0	84	0	20	0	5	0	7	1	375	376	.3

Brief notes on the importance of the parasites observed follow:

The most prevalent parasite of the digestive tract of local cattle is the gullet worm, *Gongylonema pulchrum,* which was present in 54 percent of the cattle examined. This parasite lives in the lining of the esophagus. Though often abundant, it is not regarded as serious.

The stomach worm, *Haemonchus contortus,* was found in only two animals, and the worms were not abundant in either case. This parasite lives in the fourth stomach, where it may produce serious lesions and, when present in large numbers, causes anemia.

The hookworm, *Bunostomum phlebotomum,* was identified in 25 of the cattle examined. This parasite is usually in the anterior part of the small intestine, where it sucks blood by attaching itself to the intestinal wall and causes anemia of young animals.

Two species of cooperia worms have been identified from the small intestines of local cattle. One species, *Cooperia punctata,* was found in 15 of the animals, but the other, *C. pectinata,* was found in only 1 animal.

In addition to the parasites mentioned, which were recovered at autopsy, two intestinal worms were identified by finding the characteristic eggs in the feces of infected calves. These parasites are the whipworm, *Trichuris ovis,* which lives in the cecum, and *Strongyloides papillosus,* which is found in the small intestine.

Examinations were also made of feces of young calves for diagnosis and identification of coccidian oocysts. Four species of coccidia have thus far been identified from local calves. These are: *Eimeria cylindrica* (Wilson, 1931); *E. bovis* (Zublin, 1908); *E. zurnii* (Rivolta, 1878); *E. budikonensis* (Tubangui, 1931). None of these species of coccidia occurred in large numbers, and none of the calves was diarrheic at the time of examination.

Skin lesions apparently caused by a round worm, *Stephanofilaria stilesi,* occurred in 90 percent of the cattle examined. The parasite was not found in all of the lesions examined, although the lesions are macroscopically similar. There is some indication that the parasites may occur periodically, a circumstance which would account for their absence in some lesions at certain times.

The cattle grub, *Hypoderma lineatum,* was found in the skin on the backs of 26 percent of the cattle examined. Some of the infections have been so heavy as to cause large, confluent areas of greenish-yellow degenerated fat and connective tissue around the parasites. The first-stage larvae also occur in the wall of the esophagus, where they feed and grow before migrating to the back. This parasite is recognized as being very injurious to cattle, not only causing loss in flesh and milk production, but also decreasing the value of the skin for leather.

The spinose eartick, *Otobius megnini,* was found in 45 percent of the local cattle examined. The severity of infection ranged from only a few ticks to as many as 65 in a single ear. When the ticks are numerous, the ear canal is clogged with ticks and a greasy mass of debris. The larval and

nymphal ticks in various degrees of engorgement may be found in the ears of local cattle at all times of the year. Life-history observations indicate that the development is much faster here in Hawaii than on the mainland. Fully engorged nymphal ticks molted into adults 7 to 8 days after removal from the cattle. Copulation of the adult ticks occurred on the second day following molting, and the first eggs were deposited 5 days after the adults emerged. The first eggs hatched on the tenth day and practically all eggs were hatched by the fourteenth day. The daily mean temperature during the period of observation was 80° F. Evidence of the longevity of the adult tick was shown when two of several ticks kept in a jar in the laboratory lived slightly more than 9 months.

The short-nosed sucking louse, *Haematopinus eurysternus,* occurred in the ear of only one bovine. The parasite was very abundant on this host.

Bovine trichomoniasis, a venereal disease caused by the protozoan, *Trichomonas foetus,* and characterized by abortion, sterility, and pyometra, is an important disease of cattle in many parts of the United States. Whether this disease occurs in local cattle is apparently unknown. Examinations have been made of the uteri of 15 cattle but all have been negative for *Trichomonas,* although four of the uteri had pyometra. *(Cuckler, Alicata)*

POULTRY PARASITES

Cecal Worm

Life history. Detailed studies of the development of the cecal worm, *Subulura brumpti,* in the intermediate host have indicated that the eggs, at the time they are passed from the host, are infective for a number of insect intermediate hosts. When the eggs are ingested by the intermediate host, the larvae hatch and within a few hours have penetrated the intestinal wall, thereby gaining entrance to the body cavity, where further development occurs. After a period of 4 to 5 days the larvae molt and become the second-stage larvae. During this stage the larvae grow and become encapsulated in various tissues of the intermediate host. The second molt occurs 13 to 14 days after the larva enters the intermediate host, and the larva is then in the third or infective stage. No further development occurs until the larva is ingested by chickens.

Up to the present time the following arthropods have been found naturally infected with the infective larvae of *S. brumpti: Dermestes vulpinus, Gonocephalus seriatum, Ammophorus insularis,* and *Alphitobius diaperinus.* It has also been possible to infect experimentally the flour beetle, *Tribolium castaneum.* The following arthropods have not been found naturally infected, nor has it been possible to infect them under experimental conditions:

House fly, *Musca domestica*
American cockroach, *Periplaneta americana*
Burrowing cockroach, *Pycnoscelus surinamensis*
Gray cockroach, *Nauphoeta cinerea*
Sowbug, *Porcellio laevis*
Sandhopper, *Orchestia platensis* *(Cuckler, Alicata)*

Sheep. A small number of sheep from the Island of Kahoolawe have been examined for parasites. The following were found:

Spinose eartick, *Otobius megnini,* in 43 out of 60 (72 percent)
Stomach worm, *Haemonchus contortus,* in 6 out of 15 (40 percent)
Stomach worm, *Trichostrongylus instabilis,* in 3 out of 10 (30 percent)
Intestinal worm, *Cooperia punctata,* in 3 out of 10 (30 percent)
Intestinal worm, *Nematodirus spathiger,* in 1 out of 10 (10 percent)
(Cuckler)

Phenothiazine treatment. Phenothiazine was administered in single and repeated doses, chiefly in hard gelatin capsules, to a number of chickens experimentally infected with the cecal worm, *Subulura brumpti.* The drug was given in doses ranging from 0.05 to 1.0 gram, with no evidence of toxicity, enteritis, or other intestinal disorder. The following table records the results.

Table 19.—Efficacy of single and repeated doses of phenothiazine against cecal worms

Bird number	Weight of bird	Dosage	Days given	Total grams given	Worms expelled by bird on successive days				Total worms expelled	Worms remaining at autopsy		Efficacy of drug
					1	2	3	4		Alive	Dead	
	Grams	*Grams*										*Percent*
33	1290	0.10			4	[2]0			4	76	0	5.0
27	970	.25			15	[2]0			15	0	0	100.0
32	1310	.25			18	[2]0			18	46	0	28.1
38	1270	.25			9	[2]1			10	0	0	100.0
31	1025	.50			23	[2]4			27	33	3	47.6
8	1115	.50			32	[2]4			36	0	0	100.0
23	1360	.50			48	[2]0			48	1	0	98.0
25	900	.75			96	[2]1			97	1	0	98.8
28	1250	.75			42	[2]4			46	10	0	82.1
15	1420	.75			20	[2]4			24	0	0	100.0
26	1340	1.0			48	[2]0			48	0	5	100.0
45	1090	.05	3	.15	3	21	1	[2]0	25	15	0	62.5
154	1220	.05	3	.15	11	9	[2]6		26	41	0	39.0
10	1040	.10	2	.20	67	2	[2]0		69	0	0	100.0
156	1280	.10	3	.30	46	2	[2]0		48	1	0	98.0
24	1315	[1].10	2	.20	12	27	[2]0		39	32	0	54.9
155	1370	[1].10	2	.20	2	[2]1			3	15	30	68.8
157	1100	.25	2	.50	31	[2]11			42	0	0	100.0
19	1110	[1].25	3	.75	40	10	0	[2]0	50	0	0	100.0
20	960	[1].50	2	1.0	85	0	[2]0		85	0	0	100.0
48	1215	[1]1.0	3	3.0	65	1	0	[2]0	66	0	0	100.0

[1] Phenothiazine was mixed with feed, rather than administered in capsule form.
[2] Autopsy performed on this day.

These results indicate that phenothiazine in doses of 0.5 to 1.0 gram is highly effective in killing and expelling the cecal worm, *S. brumpti.* There is no evidence of toxicity, and the drug may be given individually by capsules or in the feed. *(Cuckler)*

Influence of lactose. Lactose as a possible agent for increasing the acidity of the intestinal tract has been suggested by J. R. Beach *(Hilgardia,* Vol. 1 (8), October 1925), who reported that feeding birds a ration containing 20 percent lactose increased the hydrogen-ion concentration of the cecal content. Two experiments were therefore conducted to determine what effect a 20-percent-lactose ration would have on the development of the cecal worm, *Subulura brumpti.*

In the first experiment 40 laboratory-raised White Leghorn chicks, which had been fed commercial growing mash up to 2 weeks of age, were divided into 2 groups. The check group, consisting of 15 chicks, was fed a basal ration composed of the following parts: Yellow corn, 34; wheat bran, 13; wheat middlings, 20; brewer's yeast, 5; peanut meal, 7; soybean meal, 8; alfalfa meal, 7.25; oyster shell, 3; codliver oil, 1.25; and salt, 0.5. The 25 chicks in the experimental group were fed 80 percent of the basal ration plus 20 percent lactose. Four days after the diets were first offered, each chick was fed 100 infective cecal-worm larvae obtained from naturally infected beetles. Three weeks after infection the chickens were autopsied, the hydrogen-ion concentration of the cecal contents was electrometrically determined, and the worms in the ceca were counted. The second experiment was identical except that the chicks were 3 weeks old when diet feeding began, and that the test ran for 4 weeks after infection. In this second experiment there were 24 chicks in the check lot, and 33 in the experimental lot. The results of both experiments are summarized in table 20.

Table 20.—Effects of feeding 20-percent-lactose ration on development of the cecal worm in poultry

Ration	Weight of chickens		Cecal *p*H		Number of worms present	
	Basal	Lactose	Basal[1]	Lactose[2]	Basal	Lactose
	Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
EXPERIMENT I						
Minimum	280	250	5.50	4.80	75	1
Maximum	460	480	7.20	5.80	95	87
Average	*352*	*343*	*6.54*	*5.32*	*84.4*	*54.2*
EXPERIMENT II						
Minimum	350	210	5.62	4.84	8	0
Maximum	680	520	7.50	6.15	79	65
Average	*513.7*	*391.5*	*6.59*	*5.31*	*35.4*	*19.3*

[1] Determined on only 12 of the 15 chicks in Experiment I.
[2] Determined on only 20 of the 25 chicks in Experiment I.

The results show that in both experiments significant differences in cecal acidity and average number of worms occurred between chickens that were fed basal rations and those that were fed lactose rations. In the second and longer test, however, chickens fed the lactose ration weighed less than those in the control group. *(Cuckler, Alicata)*

Tapeworm Infection

Influence of lactose. The annual reports for 1939 and 1940 noted that birds on plant-protein rations developed more tapeworms on the average than those on animal-protein rations. Since the animal-protein rations contained 10 percent fish meal and 6 percent skim milk, it appeared possible that these feeds had reduced the tapeworm infection by increasing acidity in the small intestine.

An experiment was therefore conducted to test the effect on tapeworm infection of feeding lactose. Two groups of White Leghorn chicks were maintained on a commercial growing mash for 20 days, after which the check group, consisting of 21 birds, was fed the basal ration; and the experimental group, consisting of 22 birds, the lactose ration described above (see *Cecal Worm).*

After the chicks had been on the experimental diets for 1 week, each was fed 100 tapeworm larvae (cysticercoids) of *Hymenolepis exigua.* Two weeks after infection, all the chicks were killed. Autopsy showed that birds on the basal ration harbored an average of 59.5 tapeworms, and those on the lactose ration, 30.8 tapeworms. The *p*H's of the small intestines of three birds on the basal ration were electrometrically determined and found to range from 6.1 to 6.4. For three birds on the lactose ration the range was from 6.3 to 6.4. This variance would not indicate that the presence of lactose altered the acidity of the small intestine, and the reduction of parasitism in the lactose-fed birds would seem to be due to other properties of the lactose. *(Alicata, Cuckler)*

Soil and Plant Investigations

Hawaii's greatest natural advantage is its climate, or more specifically, its range of equitable climates which, together with rich resources of irrigation water, make possible the growing of many diverse crops. Practically none of these crops is indigenous; rather have almost all been introduced from the tropical, subtropical, and even temperate zones of the world. Hawaii, therefore, is not only a large-scale laboratory in which the energy relationships of widely different crops can be measured under many climatic conditions but also one in which the preliminary, commercial exploitation of particular crops is being conducted. From the agriculturist's viewpoint the broad term "adaptation" includes all of these relationships. Obviously, a plant may be adapted to the soils, seasons, and climate, but unless it also contributes to the agricultural complex it is of little practical value. Conversely, a plant may be adapted and of great commercial value and still be susceptible of great improvement. The genius of the physiologist and geneticist has been repeatedly demonstrated in this field. Thus the term "adaptation" is a relative one.

The following sections deal with many facets of the general field of adaptation in its broad sense. Obviously, not all are of equal importance, and it is evident that rigid selection not only of crops but of the problems must be exercised.

SOIL STUDIES

PHYSICAL AND CHEMICAL PROPERTIES

Hawaiian Soil Colloids

Soil colloids play a dominant role in the moisture relationships of soils; they have a direct bearing on soil tilth and soil erosion. The absorption properties of the soils and availability of many of the essential plant food elements also depend upon the soil colloids. Studies have been initiated concerning the mineralogical and chemical properties of colloids isolated from typical Hawaiian soils; for comparison, colloids from two Tahiti soils were also considered.

Dehydration curves were run on the isolated colloid samples, between the limits of 100° to 700° C. The interpretation of these curves showed that the samples all contained the clay mineral, kaolinite. No evidence was

found of the presence of bauxite, goethite, or montmorillonite. The estimated percentages of kaolinite ranged from 5 to 65. Colloids from Aiea and Poamoho, Oahu, had the greatest amounts of kaolinite; a colloid from the Hilo coast, Hawaii, contained the smallest amount. Samples of these same colloids were sent to Dr. W. P. Kelley, University of California, for crystal X-ray analyses.

The chemical investigations of the colloid samples included determination of the ultimate chemical composition, the base-exchange capacities, and the free iron oxides. Amounts of free iron oxide ranged from 4 to 43 percent. The hydrogen-sulfide treatment, which was used to remove this free iron oxide, decreased by at least 50 percent the base-exchange capacities of all colloid samples except the two highest in kaolinite. The base-exchange capacities of the high-kaolinite colloids were virtually unaffected. These two samples also had the lowest initial base-exchange capacities. *(Dean, Tanada)*

Granular Nature of Hawaiian Soils

Work on structure of local soils has continued because of the evident importance of this property in local agriculture. After samples of soil had been churned in liquid for a specified time, the sizes of granules which resisted dispersion by this treatment were determined by elutriation.

When pure water was used for the dispersion, only about 7 percent of an air-dry Poamoho soil existed as individual particles or in aggregates smaller than 0.02 millimeter in diameter. When the same material was churned in weak solutions of ammonium, sodium, or potassium hydroxide, the granules tended to disperse and aggregates disappeared.

Stability of granules appears to increase as the original moisture content of the sample decreases. On the other hand, when some soils are heated to 300° C., the capacity for dispersion is about equal to that of air-dry soil. *(Wadsworth, Inn)*

Vapor Pressures of Soils

Apparatus has been designed and built which permits the accurate measurement of aqueous vapor pressures in equilibrium with samples of soil materials at different moisture levels. In this apparatus, moisture percentages are measured by a Jolly balance spring; vapor pressures are measured on a manometer filled with a light oil. The assembled apparatus, removed from the constant temperature bath, is shown in figure 8.

Figure 9 gives representative curves for the colloidal material extracted from soil from Poamoho. It is to be noted that the moisture-content—vapor-pressure curve secured by wetting dry material is significantly different

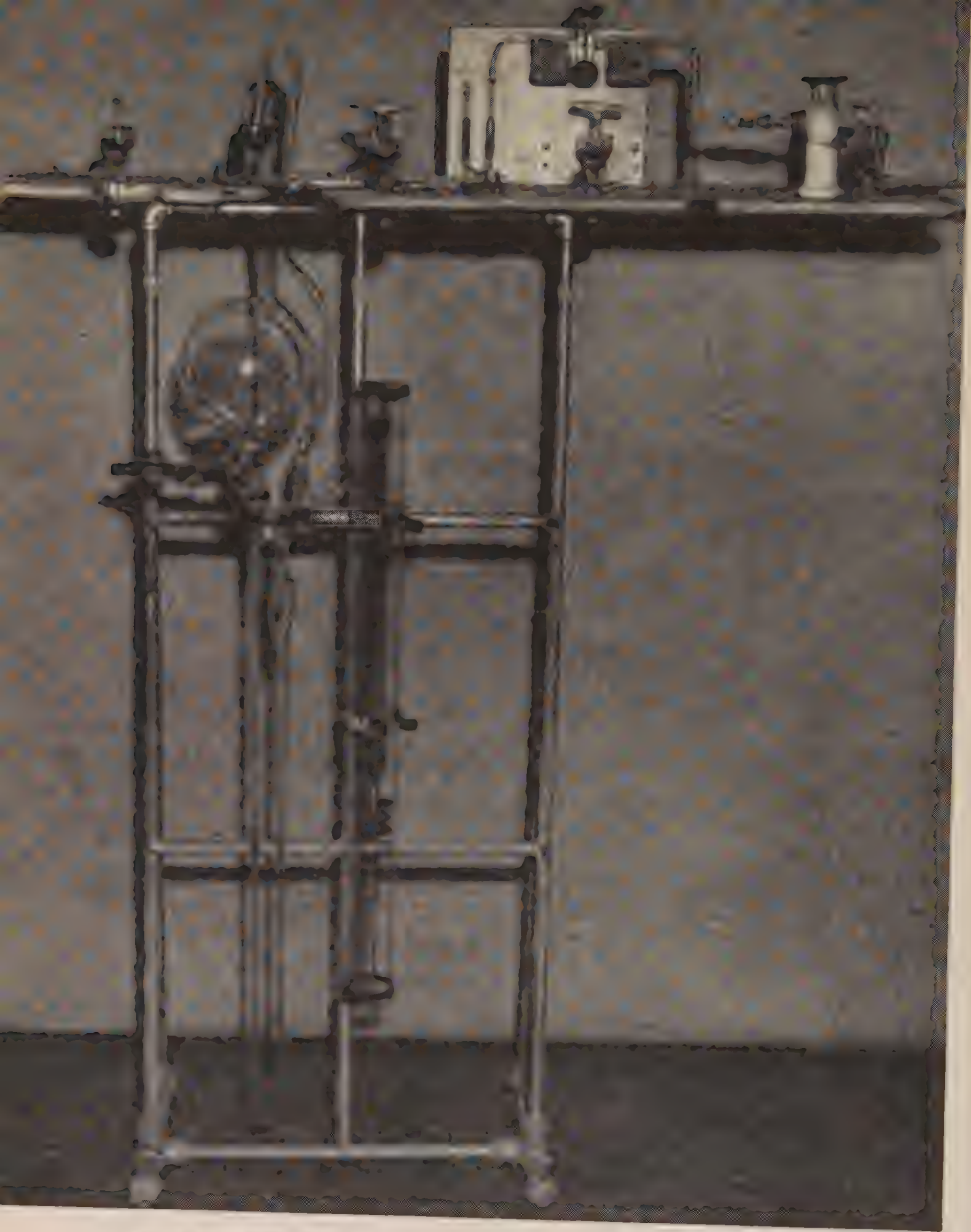


Figure 8.—Apparatus for measurement of aqueous vapor pressures in equilibrium with soils at various levels of moisture content.

from that secured by drying an originally wet sample. The fact that the material does not return to its original mass upon drying, even when the vapor pressure is reduced to zero, is of considerable theoretical interest. So far as is known, this phenomenon has never before been reported with soils or soil extractions. *(Wadsworth, Inn)*

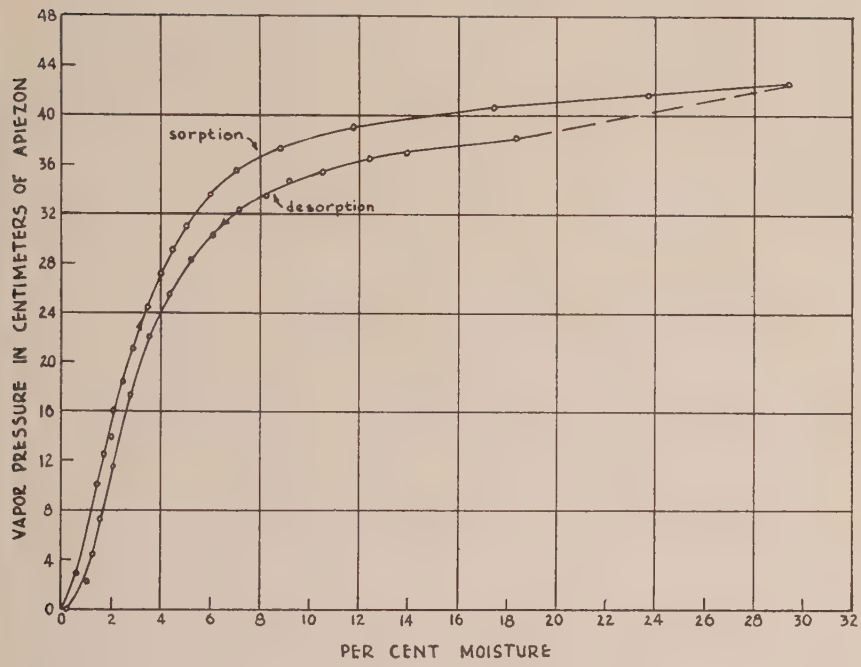


Figure 9.—Vapor-pressure—moisture-content relationship for Poamoho colloid, as determined by apparatus shown in figure 8.

BASE-EXCHANGE STUDIES

Availability of Exchangeable Calcium

Mixtures of soils and quartz sand were used in greenhouse studies to determine availability of exchangeable calcium of soils at varying degrees of base saturation. Soils were diluted with sand in such proportions that the total exchangeable calcium per pot was the same, but there were varying degrees of base saturation in respect to calcium. Sugarcane and Sudan grass were the indicator crops, and the total calcium absorbed by the crop grown in each pot was determined by chemical analysis.

The amounts of calcium absorbed by the two indicator crops were found to be directly proportional to the degree of saturation of exchangeable calcium in the soils and not to the percentages of exchangeable calcium by weight. *(Dean)*

Sorption of Potassium and Ammonium by Soils

In the annual report for 1940 it was shown that as the degree of calcium saturation of the soil was increased, the subsequent sorption of potassium

and ammonium was also increased, and that the levels of exchangeable potassium and ammonium which could be established in the soil were dependent upon the concentrations of the bases in the solutions percolating through the soils. Subsequently, two additional factors have been found to influence the sorption of potassium and ammonium by the soil.

Rate of percolation. It was found that when solutions were allowed to percolate rapidly through columns of soil, sorption of the dissolved bases was less than when percolation was retarded. It appears to follow, therefore, that movement of dissolved bases through open, quickly drained soils may result in a lower order of sorption than corresponding movement through heavy, slowly drained soils.

Level of exchangeable potassium. Soils containing small amounts of potassium removed this base from solutions more effectively than soils well supplied with the base. Under field conditions the highest order of sorption of potassium should, therefore, other factors being equal, be manifested by those soils which contain the lowest levels of the base. It is believed that this factor may be disregarded in connection with the sorption of ammonium, because of uniformly low levels of exchangeable ammonium in Hawaiian soils.

Critical concentration. It has developed that there is a critical concentration of potassium above which sorption from solutions of the base will occur and below which it will not occur. This concentration differs for different soils and is dependent in considerable degree upon the level of exchangeable potassium in the soil. Some soils were found capable of sorbing potassium at any concentration above 2 parts per million of potassium oxide. Other soils, however, were unable to take up potassium oxide at concentrations below 40 parts per million. *(Ayres)*

MICRO-NUTRIENT INVESTIGATIONS

Zinc

It has been known for some time that certain abnormal conditions of pineapple plants in Hawaii could be corrected by spraying with zinc sulfate. The investigation reported here was undertaken to study the zinc content of pineapple plants and soils in relation to the zinc-deficiency symptoms observed in the field. The findings may be summarized as follows:

(a) A relationship was found between the degree of zinc deficiency exhibited by pineapple plants and the available soil zinc. Plants grown on soils low in available zinc showed severe zinc-deficiency symptoms.

(b) Zinc was found in the greatest amounts in the meristematic tissues of the plant, that is, in the growing points and the white basal leaf tissue.

The concentration of zinc in the growing point was the only critical index related to the deficiency symptoms exhibited by the plants. The growing points of zinc-deficient pineapple plants contained considerably less zinc than normal or slightly deficient plants.

(c) Apparently, the abnormalities of pineapple plants that can be cured by spraying with zinc sulfate result directly from the soil's inability to supply sufficient zinc to the plant.

Boron

Studies on the relation of soil boron to Hawaiian agriculture were completed during the last biennium. Points under consideration were the availability of water-soluble boron in Hawaiian soils, boron fixation, and the distribution of boron in three Hawaiian agricultural crops. The results of these investigations are summarized below:

(a) Definite boron-deficiency symptoms on sunflower seedlings were obtained when seedlings were grown in soils containing less than 0.7 part per million of water-soluble boron.

(b) Boron fixation was demonstrated by a neutral alluvial and an acid residual soil. The acid soil, which had a low level of water-soluble boron, fixed 20 percent of the boron from a solution having an initial concentration as low as 0.25 part per million. The neutral soil, which had a high level of water-soluble boron, fixed no boron from the lowest concentration; but in contact with an initial solution concentration of 0.5 part per million it fixed 36 percent of the boron.

(c) The sugarcane plant contains relatively low concentrations of boron; the highest concentrations are found in the meristem, elongating cane, and leaf blades. In the absence of sufficient soil boron, these parts show the greatest decrease in concentration from the normal.

(d) A study of the distribution of boron in the pineapple plant revealed that the older leaf tissue, the leaf tips, contained the highest concentration of boron. These older leaf parts also showed the most marked decrease in concentration from the normal, because of low amounts of water-soluble soil boron.

(e) Leaf samples collected from coffee trees growing in Kona, Hawaii, showed a definite accumulation of boron in the older leaves. *(Dean, Tanada)*

STUDIES OF THE HUMID-REGION SOILS

Rainfall in the agricultural areas ranges as high as 230 inches annually. Many of the humid-region soils are, therefore, highly leached. Since a permanent system of Territorial agriculture embraces the employment of large

areas of soils of this type, it appeared appropriate to study those properties of the soils which are closely associated with their productivity.

The study was based principally upon the soils of the Hilo and Hamakua coasts and Puna district of the Island of Hawaii. These include the most highly leached soils in the Territory. The Puna soils are of comparatively recent origin; those of the Hilo and Hamakua coasts are older and more highly weathered. A few soils from the humid agricultural areas on the Island of Kauai were also included in the study. In contrast to soils from the Island of Hawaii, Kauai soils are believed to be among the oldest in the Territory. The soils examined in this study were essentially clay loams and clays. All of the agricultural soils selected for the study have been planted to sugarcane for many years. Large areas on Kauai, similar to those represented in this work, are used for the production of pineapples.

The results that follow were gained from a study of soils under cultivation, except that the last section, which discusses the effect of agricultural practices, involves comparisons of cultivated and virgin soils.

Levels of Exchangeable Bases

Some of the soils were practically depleted of exchangeable calcium and magnesium, containing only a fraction of one milliequivalent of these bases per 100 grams of soil. Other soils were well supplied with the bases; maximum values were 13.5 and 4.5 milliequivalents for calcium and magnesium, respectively. Both bases were found at lower levels in the subsoils than in corresponding surface soils.

Exchangeable potassium ranged from 0.1 to 0.8 milliequivalent in the surface soils. The range was nearly as great in the subsoils. Distribution of potassium in the soil profile was dependent upon the rainfall. In the drier portions of the humid region, levels of potassium were lower in the subsoils than in the surface soils, whereas in the wetter areas the subsoils contained as much or more potassium than the surface soils.

Exchangeable manganese was found in the surface soils in quantities varying from less than 0.005 to 0.065 milliequivalent (from 4 to 60 pounds manganese oxide per acre-foot of soil). Manganese was present in still smaller amounts in the subsoils. Many of the subsoils did not contain detectable amounts of exchangeable manganese.

Levels of Total Bases

Some of the soils contained very low levels of total calcium. In extreme cases, levels were as low as 0.15 percent calcium oxide in the surface soils, and about half this amount in the subsoils. Other soils were much better supplied with calcium, especially the young soils of the Puna district, which contained as much as 3 percent calcium oxide. From 2 percent to more than

50 percent of the total calcium in the surface soils was present in exchangeable form.

Magnesium was present in all soils in substantial amounts, reaching extremely high values (more than 9 percent magnesium oxide) in the young Puna soils. Subsoils were generally as well supplied with this base as the surface soils. Smaller proportions of magnesium than of calcium were present in exchangeable form, that is, from less than 0.4 to 11 percent in the case of the surface soils.

In the soils examined, magnesium was present in larger amounts than was calcium. The fact that the parent rock is richer in calcium than magnesium would indicate that calcium is the more susceptible of the two bases to loss. This fact is possibly associated with the tendency of magnesium to form secondary minerals, a property not possessed by calcium under acid conditions.

The total manganese content of the surface soils varied widely. Values ranged from a few hundredths of one percent to nearly 0.5 percent. On the whole, the surface soils and subsoils contained approximately equal amounts of total manganese. Only from a trace to about 2 percent of the total manganese was present in exchangeable form.

Base-Exchange Capacities

The capacities of the soils to retain exchangeable bases ranged from moderate to high values, namely, from about 20 to 60 milliequivalents per 100 grams of soil. Values for the subsoils were lower, principally because of their lower content of organic matter.

Most of the exchange capacity of the soils, or from about 50 to 90 percent (in the surface soils), was resident in the organic-matter fraction of the soil. The base-exchange capacity of the soil organic matter itself averaged a little less than 200 milliequivalents per 100 grams.

The base-exchange capacity of the organic matter decreases with increasing carbon-nitrogen ratio, in a statistically significant relationship.

The capacity of the mineral fraction of the soil to retain exchangeable bases was in some cases extremely low. The mineral fractions of a number of clay soils possessed less than 5 milliequivalents of exchange capacity per 100 grams. The lateritic nature of the soils was seen to be reflected in these low values.

Acidity

The acidity of the soils ranged from *p*H 4.5 to *p*H 6.0 in surface soils. The subsoils were generally less acid than the surface soils. The less acid condition of the subsoils was believed to be the result of lower levels of organic matter in this horizon.

Ultimate *p*H values covered a considerable range, varying from 3.6 to 4.7 in the surface soils. The subsoils were incapable of becoming as acid as the corresponding surface soils. Ultimate *p*H values in the subsoils ranged from *p*H 4.5 to *p*H 5.4.

The soils of large areas appear nearly as acid as it is possible for them to become. Some of the surface soils were thus within 0.5 *p*H unit of ultimate acidity. About half of the subsoils examined were still closer to this condition.

The soil organic matter was found to influence markedly the ultimate *p*H of the soil. Removal of this material from the soils increased ultimate *p*H from 0.3 to nearly 2.0 *p*H units. Thus the higher ultimate *p*H values of the subsoils are apparently associated with their lower content of organic matter.

The lateritic nature of the soils studied appears to be reflected in the high ultimate *p*H values obtained for the mineral fractions of some of the soils. These values ranged as high as *p*H 6.3.

Organic Matter, Nitrogen, and Carbon-Nitrogen Ratio

The soils contained unusually high levels of organic matter. In the surface layer, values ranged from 7 percent to as high as 27 percent. Although levels of organic matter were lower in the subsoils, they were in many areas very substantial, ranging from 2.5 to 17 percent. Heavy original vegetation, combined with semianaerobic soil conditions in areas of excessive rainfall, apparently accounts for the high levels of organic matter in many of the humid-region soils.

The nitrogen contents of the soils were generally high. Nitrogen in the surface soils varied from 0.2 to 1.0 percent. In the subsoils, nitrogen was present in smaller amounts. The high levels of nitrogen in many of the soils are apparently associated with the factors responsible for the large quantities of organic matter in these soils.

The carbon-nitrogen ratios were high, and varied within wide limits. In the surface, horizon values ranged from 11 to 20. The range was still wider in the subsoils, or from 11 to 26.

Rainfall Relationships

An unusual opportunity to study the influence of rainfall upon the chemical properties of the soil was offered by the soils of the Hilo and Hamakua coasts. Factors other than rainfall which influence soil properties, such as the composition and age of the parent rock, temperature, and past and present vegetation, were apparently practically constant in this region. The following statistically significant relationships between rainfall and the properties of the soil considered in this study were established:

Increasing with increasing rainfall—
- Carbon-nitrogen ration
- Proportion of total base-exchange capacity resident in the soil organic matter

Decreasing with increasing rainfall—
- Exchangeable calcium
- Exchangeable magnesium
- Proportion of total calcium in exchangeable form
- Base-exchange capacity of the soil
- Base-exchange capacity of the mineral fraction of the soil

Influences of Agricultural Practices

An attempt was made to determine to what extent the properties of the soils under consideration have been modified by agricultural practices. Accordingly, a study was made of virgin and comparable cultivated soils from the Hilo and Hamakua coasts. The apparent effects of 25 or more years of sugarcane production on these soils may be summarized as follows:

Levels of exchangeable calcium apparently have not been reduced as a result of agricultural practices. Presumably, therefore, losses of calcium from cropping have been compensated for by liming and by using calcium-containing fertilizers and amendments.

Levels of exchangeable magnesium appear to have decreased as a result of practices associated with the production of sugarcane. Magnesium has seldom been added to these soils except incidentally as a constituent of the cruder forms of potash fertilizers.

Evidence was obtained that the levels of exchangeable potassium in the cultivated soils have increased since the land has been under cultivation. This increase is especially marked in the subsoils, which in a number of areas contained several times as much exchangeable potassium as corresponding virgin soils.

Exchangeable manganese existed at about the same level in both virgin and agricultural soils.

The cultivated soils were less acid than the virgin soils. In some instances the differences were slight; in other cases the cultivated soils were markedly less acid. The less acid condition of the cultivated soils is apparently not the result of higher levels of exchangeable bases, but rather the result of losses in soil organic matter.

Organic matter and nitrogen were found to be at somewhat lower levels in the cultivated soils than in the virgin soils. To what extent this situation is associated with the production of sugarcane and to what extent it may be due to erosion of the surface soils, is not clear. *(Ayres)*

PLANT PHYSIOLOGY

CLIMATE AND CROP PRODUCTION

Environmental Factors and Fertilizer Requirements of Sugarcane

Climate has a very marked effect on the yields and quality of crops. Here in Hawaii, where crops are grown the year around and where the type of climate experienced in one area is very different from that noted in another only a few miles away, it was possible to set up a field experiment to demonstrate quantitatively the relative importance of soil and climate. This work has been conducted through the cooperation of and with facilities furnished by the Experiment Station of the Hawaiian Sugar Planters' Association.

Sugarcane was grown at Waipio, a low-rainfall, irrigated region of high sunlight intensity, and at Kailua, a moderate-rainfall, cloudy region. To eliminate the soil factor as a variable, soil from the Kailua field was taken to Waipio. Cane grown in the Kailua soil under Waipio conditions was comparable to that grown in Waipio soil at Waipio. Complete analyses of leaves indicated that there were no deficiencies at either place.

The total 24-hour-per-day temperatures averaged, for the 22-month period, 72.9° F. at Waipio and 72.4° F. at Kailua. Sunlight conditions, however, differed greatly.

Complete growth records, compiled month by month, included the number of leaves, their size and rate of emergence, and the vertical growth of the plant, as well as the circumference of the stalk, and the density of the plants per foot of row. Finally, at the end of 22 months, the crops were harvested. Despite the similarity of soil and temperature, the Waipio crop yielded 134 tons per acre of high-quality cane (18.6 tons of sucrose), while the Kailua crop yielded only 65 tons of medium-quality cane (7.2 tons of sucrose).

All attempts to correlate this difference in growth with soil or with levels of nitrogen, phosphorus, potash, or calcium in the plant were without success, but an almost perfect correlation ($+0.999$) was obtained when the physical factors of leaf area, crop density, and sunlight were considered. To determine this correlation, the Kailua crop was calculated from the growth made at Waipio, introducing into the equation the Kailua data for sunlight, leaf area, and crop density. On the basis of these calculations, the plants at Kailua should have been 286.1 centimeters tall, as compared with 540.0 centimeters for those at Waipio. The average height of the Kailua plants was actually observed to be 295.7 centimeters tall, a very small departure from the calculated value.

Since the differences in crop yield and quality are so largely dependent upon the weather and not upon soil, it is clear that the application of water and fertilizer to a crop cannot be based on any empirical program determined at the time the crop is started. Rather, the control of the crop must be based upon the theory that the plant is continually responding to factors of environment, some of which encourage photosynthetic and other synthetic activities while others encourage the utilization in growth of the materials so built. If growth is greater than the atmospheric energy permits, there will be a reduction of reserve material; if less, the reserve material will accumulate. In order to follow this continually shifting fulcrum, it is necessary to find some tissue in the plant which can be used as an index. In sugarcane this was found to be the sheaths of certain leaves. Where the plant is balanced with its environment, the total sugar level of this tissue is about 10 percent. If growth is excessive in relation to the atmospheric energy, the sugar level drops. If growth is below what the environment permits, the sugar level rises. The sugar level of this tissue is regarded as the primary index.

When the primary index is normal (about 10 percent), the plants are producing the maximum high-quality growth that can be expected of them under the particular climate. When the index drops, excessive growth is indicated and poor quality results. When such a condition occurs, certain secondary indices are examined, the most important of which is the moisture index. The moisture index is the moisture percentage of the same sheaths that are used for the primary index. A high moisture level encourages excessive growth, and a reduction in irrigation reduces the moisture level and raises the primary index back to normal. During periods of high day and night temperatures, growth can be checked through irrigation control.

When the primary index rises, however, photosynthetic activity exceeds growth activity. Under such conditions very high qualities are obtained, but the total yield is low. Factors favoring this condition are high insulation coupled with cold weather, especially at night, drought, and deficiencies of soil elements. If atmospheric temperatures are the cause, nothing need be done except to maintain the moisture level at an optimum in order to take full advantage of the situation. If temperature is not the factor, then the moisture index is consulted. If this is low, the irrigation program (or rainfall) is first reviewed, and changes are made in the interval between irrigations. However, if the irrigation program or rainfall, as reviewed by experience, seems adequate, the other secondary indices are examined—the most likely being the nitrogen index (the total nitrogen content of the green blades associated with sheaths already mentioned). From this index the grower

can determine not only whether more nitrogen is needed but also rather precisely how much. Potash, phosphates, and calcium levels are similarly pictured by the sheaths of these leaves.

Through the use of this program, developed at the Hawaii Agricultural Experiment Station, much of the guess work in crop management is eliminated. Economically, the program pays for itself many times over in savings of fertilizers and water—not to mention the high yields of quality crops. *(Clements, Kubota, Akamine, Moriguchi*[1]*)*

TRANSLOCATION

Movement of Solutes Within Plants

Sugarcane. A study of movement of solutes in sugarcane, and particularly the movement of sugar, nitrogen, phosphorus, and potassium from the seedpiece to the germinating buds, was conducted to determine whether the inhibition of buds in the down position was due to a removal of the necessary food materials by the more dominant up buds. The analytical work, however, is not yet completed.

Sausage tree. During the summer of 1940, the fruits of the sausage tree were again measured at weekly intervals to repeat work of the previous year. The volume of several clusters of fruits was determined through water displacement. By collecting fruits each week, it was possible to determine the amount of dry material which had to move into the fruits each day to account for the observed growth. This value, then, can be converted into the amount of hexose sugar which must move into the cluster of fruits each day. The peak of translocation was observed during the week ending July 6 (table 21), when an average daily movement of 42.6 grams of hexose sugar was obtained. As during the previous summer, the greatest movement was observed during the first 5 weeks of fruit growth, indicating again that the movement of sugars in the plant is a process involving metabolic work on the part of the sieve-tube protoplasm of the phloem. *(Clements, Kubota)*

TOXICOLOGY

Arsenic Studies

Bean, Sudan-grass, and tomato plants were grown in culture solutions of varying arsenic concentrations in order to determine the relative toxicity of trivalent and pentavalent arsenic.

[1] Staff of the Experiment Station, Hawaiian Sugar Planters' Association.

Table 21.—Growth records and other data relating to the movement of carbohydrate material into the fruits of the sausage tree

1940	June 16	June 23	June 29	July 6	July 13	July 20	July 28	Aug. 11	Aug. 24	Sept. 15
Average volume per cluster (cc.)	462	1,510	3,046	5,307	7,525	8,238	8,563	8,878	8,957	9,243
Increase over volume of preceding week (cc.)	462	1,048	1,536	2,261	2,118	813	325	315	78	286
Daily increase in volume (cc.)	33	150	256	323	303	116	41	23	6	13
Green weight per cc. of tissue (gm.)	1.031	0.980	0.987	0.994	0.979	0.978	0.970	0.978	0.976	0.993
Average green weight per cluster (gm.)	476	1,479	3,005	5,275	7,255	8,059	8,306	8,685	8,742	9,180
Total dry weight per cluster (gm.)	57.6	179	364	638	878	990	1,030	1,164	1,329	1,689
Daily increase in dry matter (gm.)	4.12	17.34	30.77	39.23	34.24	16.04	4.96	9.56	12.7	16.4
Carbon equivalent for dry matter (gm.)	1.79	7.54	13.37	17.05	14.88	6.97	2.16	4.15	5.52	7.13
Hexose equivalent for dry matter (gm.)	4.48	18.85	33.43	42.63	37.20	17.42	5.40	10.38	13.8	17.82

The three species of plants varied in tolerance toward arsenic, but for all three, trivalent arsenic was lethal in lower concentrations than was pentavalent. The differences in toxicity were not due to lack of absorption of pentavalent arsenic, as may be seen from table 22.

Table 22.—Tolerance to and absorption of trivalent and pentavalent arsenic by indicator plants

Plant	Lethal concentrations of arsenic		Accumulation of arsenic by apparently healthy plants	
	Trivalent	Pentavalent	Trivalent	Pentavalent
	Parts per million	*Parts per million*	*Parts per million*	*Parts per million*
Bean	2.8-3.6	12-15	1-2	7
Tomato	11-15	120-150	12	74
Sudan grass	11-15	90-120	15	98

It has been reported (1940) that higher levels of phosphate in the medium decrease the susceptibility of plants to arsenic. Further studies indicate that by increasing the amount of phosphate in a culture solution the absorption of pentavalent arsenic is materially reduced. But, it is also clearly shown that phosphates have no effect upon the absorption of trivalent arsenic by plants grown in solution.

In work now in progress with plants grown in soil, the influence of phosphate does not appear to parallel the work in solutions. So far there is no suggestion that phosphate reduces the absorption of arsenic. *(Munson)*

SEED STUDIES

Germination of Koa Haole

The local importance of koa haole *(Leucaena glauca)* as a livestock feed has recently induced new plantings by ranchers, but unfortunately, these plantings have resulted in very low germination. Dormancy or delayed germination in seeds of this crop was found to be due to the presence of very thick, waxy-layered seed coats which hinder the absorption of water by the seeds. Germination has been increased only by treatments which altered the nature of this impervious seed coat.

Mechanical scarification in a revolving container, with the seeds subjected to the abrasive surface of the inside wall, is an effective and practical method of inducing germination in quantities of seeds.

Soaking the seeds from 1 to 2 hours in a 52-percent-sulfuric-acid solution (two parts of cheap commercial 78-percent acid plus one part of tap water) will give germination as satisfactory as mechanical scarification (around 90 percent). By continuing to add a little of the original 78-percent acid to the drained-off acid after each treatment, the acid solution can be used over and over.

Soaking the seeds for 5 to 10 minutes in water maintained at a temperature of about 70° C. was less effective than mechanical or acid scarification, but it did increase germination to 70 percent, as compared with around 10 percent (at best 15 to 20 percent) for untreated seeds. A more practical means of obtaining approximately the same result was to heat the water (3 quarts to a pound of seeds) to about 80° C., turn off the heat, place the seeds into the hot water immediately, and let the whole cool off to lukewarm temperature (about 40° C.) or to room temperature.

Acid-scarified seeds should be washed with water, and either acid-treated or hot-water-treated seeds should be dried before sowing to facilitate handling. These treated seeds (including the mechanically scarified seeds) can be stored under ordinary storage conditions for a long time without losing their germinative capacity to any great extent. *(Akamine)*

Germination of Grass Seed

Low germination of forage-grass seeds in Hawaii is a serious problem to ranchers and others interested in grass propagation. Because of their low germination, many species (particularly those of recent introduction by this station) are not widely spread throughout the Territory.

The behavior of seeds of eight grass species which normally produce low germination was thoroughly studied. The causes of dormancy or delayed germination in these seeds were determined, and methods to break the dormancy were developed. Germination studies were made in soil flats in the greenhouse and in petri dishes in the laboratory. After studying various chemical and physical treatments for breaking seed dormancy, the following conclusions were drawn:

(a.) Germination of the seeds of *Sporobolus wrightii* and *Panicum prolutum* is hindered by the nature of the seed coats, which prevents an adequate gas exchange (oxygen intake and carbon-dioxide output) through the seed coats. Altering the seed coats by soaking the seeds in water, cutting the seed coats, scarifying with concentrated sulfuric acid, or subjecting the seeds to daily alternating temperatures promotes the necessary gas exchange in the process of respiration and thus increases germination.

(b.) Germination of the seeds of *Sporobolus airoides, Poa pratensis, Cynodon dactylon,* and *Pennisetum setosum* is hindered partly by the nature of the seed coats and partly by lack of some internal respiratory and perhaps nutritive stimulus. Alteration of the seed coats by the above methods improves germination. When respiratory stimulants like ammonium thiocyanate and vitamin C are given to seeds of *Pennisetum setosum,* germination is increased. Germination of *Sporobolus airoides* seeds is also benefited by vitamin C. Potassium nitrate improves germination of all four of these species, the role of the chemical being one of respiratory stimulus or perhaps one of nutritive stimulus.

(c.) The cause of low germination in the seeds of *Paspalum notatum* is the presence of tough hulls which enclose the caryopses and prevent maximum expansion of the embryos. Acid scarification, or removal of the hulls, increases germination.

(d.) Poor germination of the seeds of *Pennisetum ciliare* is due partly to secretion of an inhibitor by the hulls, and partly to the gas-impervious nature of the seed coats. Removing the source of the inhibitor or adsorption of the inhibitor by charcoal or soil particles causes improved germination. Altering the seed coats is also of benefit. *(Akamine)*

Seed Storage

Studies of the effect of relative humidity and temperature on viability of stored crop seeds have been completed, and the final report is in the process of preparation. After about 6 years of storage, it has been found that the temperature and the relative humidity in Honolulu (77° F. and 70 percent, respectively) are too high for the preservation of vitality of seeds.

In general, the vitality of seeds can be maintained if either the relative humidity or the temperature of the storage medium is held at a level far below that of the air. Relative humidities of 15 to 45 percent, even at prevailing room temperature, are excellent storage media. Temperatures of 45° to 50° F. without humidity control are equally effective in prolonging the life of the seeds. The ideal storage condition, however, is one in which both humidity and temperature are kept low.

Unless humidity can be controlled, storage of air-dried seeds in airtight containers is detrimental to viability at all temperatures. A very dry atmosphere can be obtained by placing some cheap drying agent, such as calcium chloride or quicklime (commercial grades), at the bottom of an airtight container in such a way that it will not be in contact with the seeds. *(Akamine)*

AGRONOMIC CROPS

With the prospect of partial or complete cessation of imports of animal feed, emergency planning in the agronomic field has centered around local production of crops needed to provide complete rations for livestock, especially for dairy animals, swine, and poultry.

Maximum production and availability of food and feed involve various forms of preservation to supplement the local practice of utilization in fresh form throughout the year.

Even greater, since demands of defense activities have exhausted the already scant labor supply, is the need for development of agricultural machinery for all phases of production.

Because of the emergency, some crops are being planted and some practices are being adopted at present that would be uneconomical during normal times; nevertheless, it is already apparent that advances in local agriculture after the war will result from experience gained in meeting current demands.

AGRICULTURAL MACHINERY

Even before the declaration of war a list had been prepared of machinery needed to carry out the emergency food- and feed-production program. The list included tractors, planters, cultivators, fertilizer attachments, bean-cutting attachments, power mowers, overhead-irrigation equipment, corn binders, and harvester combines. Soon after the war began, a considerable amount of this machinery was brought into the Territory by the Federal Government, and one unit of each type was assigned to this station for experimental work in developing techniques for local crops and in determining changes necessary for more efficient performance under Hawaiian conditions.

Much has yet to be learned about adapting these machines to local conditions, but already the following statements appear justified:

Wheel-type tractors, equipped with rubber tires, perform satisfactorily on relatively level areas that permit flat and straight-row culture, but are of limited use on sloping land where contoured rows and ditch irrigation are utilized.

Two-row planters operate satisfactorily for practically all crops. It was necessary, however, to determine the sprocket combinations for the several crops and to grind special seeder plates for certain local varieties.

Two-row cultivator attachments operated acceptably in most areas when cultivation was frequent enough to destroy weeds when they were quite small. Shovel-type attachments are difficult to use because they do not scour in most Hawaiian soils when the latter are moist.

Figure 10.—Power-driven corn binder, which will operate successfully in a field of Napier grass yielding as high as 20 tons of green forage per acre.

The fertilizer equipment ordered was for attachment to cultivators rather than to planters. However, under Hawaiian conditions it is almost essential that most of the fertilizer be applied at the time of planting if rapid initial growth is to be obtained.

Overhead-irrigation equipment consisting of portable pipe and a gasoline-driven centrifugal pump is satisfactory for most small crops. It permits flat straight-row culture on sloping lands and makes possible the use of various machines not adapted to ditch-irrigated plantings.

A corn binder operated by a power take-off from the tractor proved quite satisfactory in harvesting certain types of forage crops. Corn, sorghum, pigeonpeas, koa haole, and desmanthus were effectively cut and bound. The machine can also be used in cutting Napier grass and Guinea grass, as it is sufficiently sturdy to cut easily through the very heavy growth. Certain changes in the design of the binder would add appreciably to its effectiveness and adaptability. A shortening of the hitch or a direct mounting of the binder on the tractor would increase maneuverability in the relatively small fields with short, furrow-irrigated rows that are common in Hawaii. Widening of the throat and lengthening of the cutter bar would aid in cutting perennial Napier and Guinea grasses, which develop crowns

up to 15 inches in diameter. Modifications in cultural practices, such as "offbarring" these grasses to restrict the diameter of the crowns, would also increase the value of the machine.

The combine harvester, of the rasper-bar type with a 6-foot cutter bar, is equipped with an auxiliary engine, a pick-up attachment, and a sacking platform. This type of machine operates satisfactorily as a stationary thresher for relatively dry material, although its capacity is somewhat limited where the crop is bulky or large-stemmed. However, its use for direct combining in the field is hampered by Hawaii's relatively high humidity and frequent showers. Also, it is difficult to maneuver on short rows and sloping land.

Although these agricultural machines have limitations under certain adverse conditions, they offer distinct possibilities for mechanizing many phases of production of food or feed crops in Hawaii. Modifications in the construction of the machines will increase their adaptability to local conditions. Decreases in cost of production, especially in cost of labor, may occasion innovations and permanent changes in crop production.

The corn binder, or an adaptation of it, could revolutionize present methods of producing roughage feeds. The cost of cutting Napier and other coarse perennial forage grasses by hand often approximates half the total cost of production. Cutting these grasses with the corn binder will probably be much more economical and swifter. Pigeonpeas, in spite of their excellent growth and yield, have in the past been used almost entirely for grazing because of high costs of hand cutting and threshing. Mechanical cutting and threshing will undoubtedly increase the crop's uses. Perennial koa haole, which is especially difficult to cut with a cane knife or sickle, offers excellent possibilities as an economical source of leguminous forage if it can be harvested mechanically. Annual grain crops such as corn and sorghum may be grown in increased acreages in upland areas not adapted to sugarcane and pineapples if mechanical planters, cultivators, binders, and threshers are used. *(Ripperton, Takahashi, Murphy)*

SOILAGE CROPS

Preservation

Drying. Crops have seldom been dried in Hawaii, primarily because of year-round availability of the fresh product. However, under present conditions it might be unusually advantageous to dry them. Dried surpluses could be preserved; dried crops would take less space in storage and shipment; and dried products could be introduced into locally prepared feeds to give them variety. Air-drying is not feasible in zones of moderate and high rainfall,

but dry lowlands on the leeward sides of the islands provide good drying conditions during most of the year. It does not appear feasible to import or construct special driers of sufficient capacity to handle bulky crops. However, the large rotary, direct-flow driers used by local pineapple canneries for production of pineapple bran could be utilized, during periods when the canneries are not operating to full capacity.

To test feasibility of drying forage, a 1-ton lot of freshly cut koa haole was chopped in an ensilage cutter and, through cooperation with a local pineapple company, run through a large drier. No difficulty was encountered in the drying process and the resulting product, when ground in a hammer mill, had the appearance of first-grade alfalfa-leaf meal. It had a protein content of 12.72 percent. The dried meal was used subsequently in a feeding trial. Other leguminous forages such as pigeonpeas and desmanthus can no doubt be similarly dried.

Considerable increases in acreage planted to sweetpotatoes would result in surpluses and culls which could be dried and utilized as feed. Preliminary trials showed that sweetpotatoes shredded with a cossetting machine could be air-dried readily. A power-driven shredder, a modification of a machine described by F. A. Kummer of the Alabama Polytechnic Institute, was built in cooperation with the Experiment Station of the Hawaiian Sugar Planters' Association, and experiments are under way to determine the feasibility of both air-drying and mechanical drying of the shredded material. *(Ripperton)*

Ensiling. Under Hawaiian conditions, practically all forage crops are perennial and provide a continuous source of fresh feed. Normally, it is advantageous to utilize crop products when they are fresh, for maximum nutritive value and, ordinarily, highest palatability are obtained thus and the cost of preservation is eliminated. Recently, however, a number of dairymen and ranchers have constructed silos, of the erect, metal or wooden type and of the trench type, in order to extend the seasonal availability of certain roughages. If mechanical harvesting of forage crops with the corn binder becomes an established practice and provides an added incentive for cutting the entire field at one time, it will be even more necessary to store or preserve the forage in a palatable and nutritious form. If all operations of the ensiling process were mechanized to the fullest extent, the added cost of ensiling might be more than justified by the greater efficiency of harvesting the crop at the stage of growth that gives maximum yield and nutritive value.

Investigations have begun on ensiling the more common types of forages and byproducts used for dairy feeding in Hawaii, including Napier grass, koa haole, desmanthus, strip cane, and yeast slurry. Corn stover was also

Figure 11.—Members of Maui Cattlemen's Association held their field day in July 1941 at Haleakala Branch Station, where they inspected new pasture grasses and grazing experiments.

ensiled for comparison with these local forages. In preliminary trials, undertaken to observe the effect on ensilage of varying percentages of water and molasses, half-gallon and gallon bottles of the experimental forage mixtures were packed in 40-gallon barrels containing chopped forage similar to that in the bottles. This procedure produced temperatures in the bottles similar to those obtaining in larger silos. The most desirable mixtures developed by the preliminary experiments were then tested in 40-gallon drum silos, and resulting ensilages were fed to year-old dairy animals in short palatability trials.

Results to date indicate that the making of ensilage from Hawaiian crops appears to offer no special difficulties, and that the ensilage is comparable in appearance and palatability to that produced elsewhere. The ensilages prepared had a normal *p*H range of 3.5 to 4.5. When freshly cut material was ensiled, the addition of water was unnecessary. All crops produced good silage without the addition of molasses, but because of its cheapness it appears desirable to add the maximum amount compatible with a good product. Five percent of molasses appeared to be the optimum in most trials; 10 percent of molasses was definitely excessive, as it produced an acid, sticky product. When koa haole was added to Napier grass or strip cane in the proportions of 1 to 1 or 1 to 2, the product was considerably more palatable than the Napier or strip cane ensiled alone. Yeast slurry, added to strip cane

to the extent of 15 percent, increased the protein content of the ensilage on the dry-matter basis from 2.42 to 4.76 percent and definitely increased palatability.

Two experimental upright silos have been built on the University farm so that the most promising ensilages may be tested in milk-production trials. *(Ripperton, Henke, Shigeura)*

Sudan Grass

In the past, Sudan grass was extensively grown as a soilage crop in Hawaii. However, because it ratoons poorly after the first year and is susceptible to disease during the winter months, it has been largely superseded by Napier grass, which produces larger yields. However, were it not for the defects of Sudan grass, many dairymen would prefer it to Napier or panicum grass because of its higher palatability, greater leafiness, and greater nutritive value.

An attempt is therefore being made by this station to develop a strain that will be disease resistant and produce large yields. Mainland breeders who have made considerable effort to develop such strains have furnished much of their material to this station for trial.

Several selfed strains of Sudan grass received from the Agricultural Experiment Station, University of Wisconsin, in 1940 were planted in single-row plots for further study of their resistance to leaf-spot diseases. While none has shown complete resistance, several progenies appear to be sufficiently resistant to warrant further study under field conditions. During the past year several Leoti-Sudan hybrids obtained from the Agricultural Experiment Station, University of Texas, have proved somewhat resistant to leaf-spot diseases. These disease-resistant strains are diverse in their vegetative characters, but all resemble Sudan grass. They are less leafy than Sudan grass but have better anchorage and therefore should be persistent for a longer period. *(Hodges, Takahashi)*

Napier Grass

The eyespot disease of Napier grass, which reached epidemic proportions in Hawaii in December 1939, has so devastated fields throughout the Territory that the ordinary, susceptible strain of Napier has been practically eliminated as a forage crop. The fields are being replanted to disease-resistant strains developed by this station, or to other forage species. On four occasions the station distributed to about 120 growers an aggregate weight of 30 tons of stem cuttings of 8 proven disease-resistant strains developed through hybridization of Napier and Merker grasses. Strain tests with growers also provided a large volume of planting material. A number

of growers have replanted their fields from resistant stools found in diseased fields. These may be natural hybrids of Merker and Napier grasses, or even more probably, Merker grass, which is known to be quite resistant to the disease.

Reaction of growers to the station strains has been generally favorable, although some state that the stems are harder than those of Napier. Strain 34: 18 appears to be the closest approach to Napier grass in respect to softness of stem. In only one instance has eyespot been reported as affecting any of the strains. The spots occurred on the leaf margins and appeared to be associated with some abnormal growth condition. It should be recalled that neither Merker grass nor the hybrids are immune to eyespot. It appears, however, that they possess resistance in sufficient degree to escape serious infection under normal conditions of growth, and in abnormally dry periods such as the year just past.

While the resistant strains are apparently of value in controlling eyespot, much remains to be accomplished toward improving their agronomic characters, particularly succulence, leafiness, rapidity of ratooning, and adaptation to higher altitudes and to grazing. Strains are being assembled from all available sources for breeding and selection. Plants from seed of Napier grass from the highlands of Uganda, Central Eastern Africa, show especial promise. The plants are uniform and resemble standard Napier grass closely but have perhaps even broader leaves. They are quite leafy and strong tillering, like standard Napier grass. Although most of the seedlings are affected to some degree with eyespot, some appear to be resistant. Introductions from Florida closely resemble the Merker variety and are apparently highly resistant. A few seedlings exhibit unusual vigor.

Research has shown that the cause of the eyespot disease is a biological strain of the fungus *Helminthosporium sacchari,* distinct from the strains responsible for eyespot of sugarcane in Hawaii. Spores of the fungus from Napier are larger at 28° than at 21° C.; those from sugarcane are larger at 21° than at 28° C. On certain culture media, the two strains are indistinguishable; on other media they are distinct.

When the fungus from Napier is inoculated to cane, infection is produced, but the lesions are small and not of economic significance. The same is true of the fungus from cane inoculated to Napier. *(Takahashi, Ripperton, Parris)*

Legumes

Most dairymen in Hawaii feed locally produced nonleguminous roughage supplemented by protein and carbohydrate concentrates from the Mainland. When the price of milk is relatively high and shipping from the coast

is uninterrupted, the use of imported material may be feasible, but under present war conditions the Islands should produce good leguminous forages that will replace much of the imported concentrates. Increased use of strip cane as carbonaceous roughage would release lands now in Napier and other soilage grasses for production of legumes.

In the lowlands three tropical leguminous shrubs appear to offer the best possibilities for cut forage, namely, pigeonpeas, koa haole, and desmanthus. All three are perennial and well adapted to zones of moderate rainfall or, when irrigated, to dry zones. They have been used for grazing to a considerable extent here, but little is known regarding their adaptation to periodic cutting.

Pigeonpeas. Recent experiments with pigeonpeas show that all operations, from planting to harvesting and threshing, can be readily mechanized. By means of two-row planters and cultivators, the crop is cheaply established with little hand labor. Harvesting with a corn binder is practicable. Seeds can be threshed from the fresh forage, which may then be used for green feed, or the bundles can be shocked and allowed to cure in the field. By threshing the air-dried forage, three products can be separated—peas, dried leaves, and the stemmy portion. The seed can be incorporated in the rations of all types of animals; a leaf meal that is similar to alfalfa meal in use and nutritive value can be prepared; and the stemmy portion can be discarded or recombined with the leafy separate.

In many respects the pigeonpea constitutes an "all purpose" crop that might well be extensively planted at the present time. Not only does it provide seed as well as roughage, but the seed would serve as acceptable human food should the necessity arise. Since it is perennial, a large acreage could serve as a permanent reserve of animal or human food. If not needed for soilage purposes, it could be profitably pastured. Experiments are now under way to study various agronomic phases of management of the crop under periodic cutting. These include preliminary cutting back to induce low branching, height of cutting, spacing, and selection of plant types best adapted to periodic cutting.

Koa haole and desmanthus. An experiment was begun in April 1940 at the Pensacola site to determine the yield of these two species when cut periodically for forage. The entire plant was cut off at 4 to 6 inches above ground level at cutting intervals of 2, 3, and 4 months. Ample irrigation was given at all times, but no fertilizer was applied. Figure 12 shows the yield of dry matter and of protein for the first year. Desmanthus produced the higher yield of dry matter, but koa haole yielded considerably more protein.

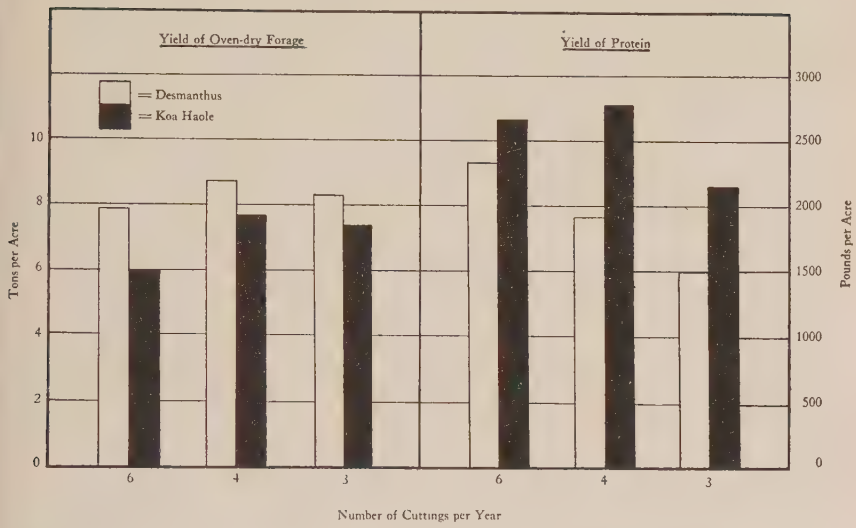


Figure 12.—Yield of oven-dry forage and protein in *Desmanthus virgatus* and koa haole during the first year at Pensacola site.

During the second year, koa haole has shown definite superiority over desmanthus in various yield criteria; moreover, the yield performance of koa haole has been better than that of the first year, indicating that persistence of this perennial shrub is not affected by such severe cultural treatment as frequent cutting close to the ground level.

Under practical conditions it has been demonstrated that the plant may be cut and harvested with a power-driven corn binder, thus materially reducing the cost of harvesting. The green forage has been dried and ground into meal that is similar in appearance and nutritive value to alfalfa meal.

A series of experiments have been installed at Poamoho Experimental Farm to investigate the following agronomic features under periodic cutting: Height of cutting, length of period from planting to first harvest, growth of plants from direct seeding versus transplanted seedlings, and response to lime and phosphates. *(Takahashi, Ripperton, Shigeura)*

PASTURE PLANTS

Adaptation of New Introductions

The station now maintains, under its own supervision or cooperatively with ranchers, 12 trial gardens for testing zonal adaptability of new introductions. These are so placed that each important zone is represented.

Much information is already available for determining the probable adaptability of species.

Temperature alone restricts certain cool-weather crops, such as vetches, to the high altitudes; and tropical crops, like koa haole, to the low altitudes. Such annuals as bromegrass and Indian yellow sweet clover would almost certainly be restricted to Zones B and C. Changing soil conditions through fertilization and disrupting the natural plant association through plowing permit, of course, at least a temporary extension of the zonal adaptation of some species.

Trial planting is the only method whereby adaptability of new species can be determined. Many grasses desirable in other parts of the world for their persistence and drought resistance, such as the grama and blue-stem grasses of the western plains of the United States, the "Mitchell" grasses of Australia, and the crested wheatgrass of northern states, have been found to have poor adaptability to Hawaiian conditions. Conversely, some species not considered important as forage in other regions are of great value in Hawaii. *(Hosaka, Ripperton)*

Evaluating Forage Grasses

Grasses are too often judged by the total bulk of forage produced. This basis may be unreliable, particularly for robust species which develop a large proportion of stem as the plant matures. Under grazing conditions the mature stem is almost entirely wasted and, even as a chopped forage, large amounts of stem reduce the palatability and nutritive value. To gain a better comparative estimate of the characteristics of certain grasses, the green leaves and immature stem portions were separated from the mature stems and dry leaves at various stages of maturity and the percentage of each determined.

Figure 13 shows the variation among strains of two grass species, grown at the University farm, with respect to total yield and proportion of palatable forage. *(Ripperton, Shigeura)*

Promising New Pasture Species

Before a new introduction is recommended and distributed to growers, it must have proved itself to be well adapted, to give a good yield of palatable and nutritious forage, and, if it is a pasture species, to be persistent. Finally, it must fill a certain need better than the species or strains now available. Comparatively few of the hundreds of introductions pass all these requirements.

The station now has on hand the following species which show promise, but have not yet been sufficiently proved to justify distribution:

Brachiaria brizantha, introduced from Texas. This has a semierect growth habit; its leaves are abundant and dark green, but rather harsh. It remained green at the Poamoho Branch Station when most other grasses had dried up, and it grew well as high as 2,200 feet at the Haleakala Branch Station. It is now being tested for palatability.

Panicum coloratum (Kifuta grass), introduced from Kenya, Africa. This grass has a rather hard stem but is more leafy than a similar species, *P. prolutum.* It is apparently quite drought resistant and has grown well from sea level to 4,000 feet. Its yield and persistence are now under test.

Paspalum malacophyllum, native of Bolivia and Brazil, introduced from Georgia. This is a soft-stemmed, leafy grass that yields well but is only moderately palatable. It produces an abundance of viable seed; consequently a grower may readily develop his own seed supply. Its persistence under grazing is now being determined.

Indigofera endecaphylla, introduced from Ceylon. This legume has prostrate stems, and once established, it covers the ground rapidly. It has grown exceptionally well at Haleakala under grazing conditions and has

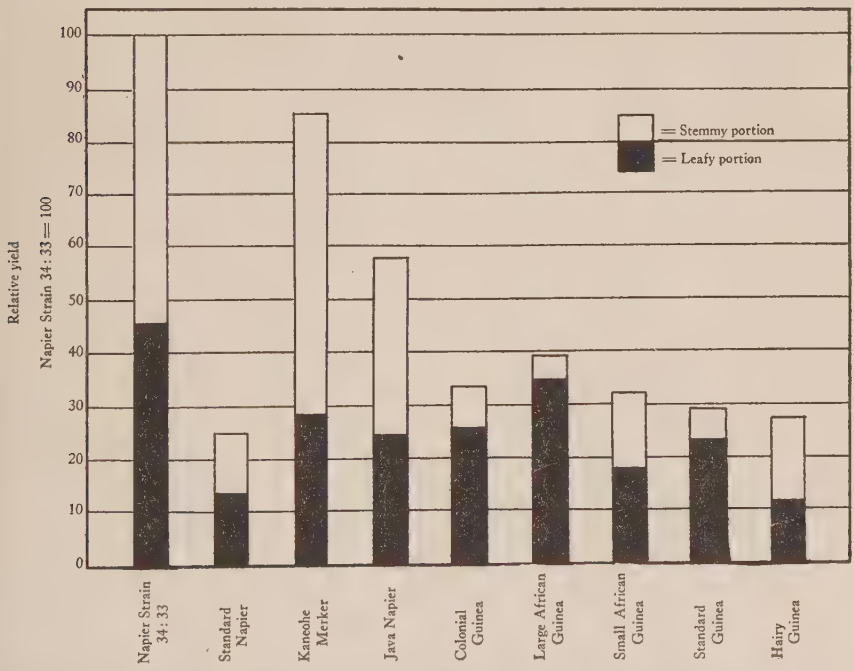


Figure 13.—Relation of green leafy portion to total yield of different strains of Napier and Guinea grasses. Green forage yield of Napier hybrid Strain 34: 33 taken as 100.

persisted under very dry conditions at Poamoho. Its principal use elsewhere is as a green manuring crop, although several investigators have reported that it also has good forage value. Its desirability as a forage is being tested further.

Desmodium canum. This legume resembles ordinary Spanish clover *(D. uncinatum)* but has smaller, more reddish flowers and more ovate leaves. When grazed, it develops prostrate stems that root at the nodes. Evidently it has been in the Territory for some time, as it occurs at numerous localities on Kauai, Oahu, Hawaii, and probably on the other islands. It is a prominent part of the pasture sward at the Kaimi Farm on Oahu, where it has persisted well under grazing. If further investigation bears out early promise, this legume should be particularly welcome because it is adapted to the wet D_1 zone, which is almost devoid of good leguminous forage species.

D. canum has excellent seeding ability. Plants at the station's Pensacola site produced an average of 44 pods to an inflorescence. Under normal conditions most of the flowers set pods averaging about 5 seeds each. The time from blooming of the plant to maturity of the seed was 12 to 19 days, depending on weather conditions. A 90-foot row produced a total of 42 ounces of seed in the first 6 months of growth.

Lotus angustissimus, introduced from Auckland, New Zealand. Though closely resembling birdsfoot trefoil *(L. corniculatus),* this legume appears to be much more vigorous and has made a strong growth in the very wet D_2 zone. Its persistence under grazing has yet to be determined. *(Hosaka, Ripperton)*

Persistence of Species

Under Hawaiian conditions, temporary pastures are of little importance. If a pasture is to be plowed or seeded, the principal concern is the selection of species that will persist over a long period. A grazing experiment was installed at the Haleakala Branch Station in 1938 to determine persistence and grazing value of a series of grasses and legumes.

The tentative conclusions at the end of the third grazing follow:

Of 67 species planted, only 12 grasses and 4 legumes were present in such amounts or showed such increase in stand that they could be expected to persist. Of this number, 7 grasses and 3 legumes may be recommended for pasture planting on the basis of their grazing qualities at this location. These are: *Digitaria pentzii, D. milanjiana,* Kikuyu grass, Bermuda grass, Rhodes grass, paspalum grass, Natal redtop, Florida beggarweed, Spanish clover, and *Indigofera endecaphylla.*

Other grasses, such as certain species of *Andropogon,* are well adapted to this location but tend to become stemmy and provide comparatively little grazeable forage. However, these grasses may be acceptable for low, dry zones where better species are not adapted.

Systematic measurement of changes in stand and in rate of spread of nine aggressive creeping grasses showed that certain ones, like *D. milanjiana,* were very persistent but had low powers of invasion into other species. Others, like panicum grass *(Panicum purpurascens),* had strong power of invasion but weak persistence in their own plots. Kikuyu grass had both persistence and power of invasion.

Carrying capacity for the various paddocks may be expressed in acres required per cow per year, as follows: Kikuyu grass basic, 1.47 acres; *D. pentzii* basic, 1.23 acres; Bermuda grass basic, 1.49 acres; and molasses grass basic, 1.08 acres. The *D. pentzii* paddock was the most desirable from many standpoints and is being continued in order to measure further changes in plant population. The high carrying capacity of the molasses-grass paddock was not due to this species but to the volunteer species which produced a fine grass mixture in the first 2 years.

The molasses-grass, Bermuda-grass, and Kikuyu-grass paddocks have been plowed and planted to single species or simple mixtures for grazing trials. To determine whether Napier and Merker grasses will persist in competition with Kikuyu, Napier hybrid 34:18 was planted in one half of the Kikuyu-grass paddock and Merker grass in the other.

Species secured from temperate regions do not persist at the Haleakala Branch Station. At the Olinda substation (3,900 feet), however, they not only thrive in the grass nursery, but certain of them are common in the surrounding pastures. *(Ripperton, Murphy, Hosaka)*

Fertilization

Pastures are seldom fertilized in Hawaii. However, fertilization should increase yields and improve quality of forage where rainfall is high and soil fertility is low.

Experiments have been installed in cooperation with a number of dairymen and a local fertilizer company. Figure 14 shows the results of a test with Kikuyu grass on windward Oahu, where the rainfall is approximately 70 inches annually. These data are evidence of substantial responses to both nitrogen and phosphoric acid. Animals showed a marked preference for forage in the fertilized areas. *(Ripperton, Shigeura)*

Legumes

Establishment of adapted forage legumes is an important pasture problem in Hawaii. Because of great diversity of climate and soils, there is need

for pasture legumes adapted to each type. Those which are at present established in pastures and are valuable as forage, by zones, are as follows:

Zones A and B, low to medium altitude and rainfall—algaroba, koa haole, desmanthus. (The first is a tree; the other two are shrubs.)

Zones B and C, low to medium altitude and rainfall—koa haole, Spanish clover, pigeonpeas, and the winter annuals, bur clover, black medic, and Indian yellow sweet clover.

Zones D_1 and D_2, low to medium altitude and high rainfall—good leguminous forage seldom present.

Zones D_3 and E_1, high altitude (above 3,500 feet)—white clover and hop clover in areas of high rainfall; and vetch, bur clover, and black medic where the rainfall is lower and more seasonal.

Although this appears to be an excellent list, actually the proportion of pastures of the Territory containing desirable legumes is small. Ecological factors governing distribution of the pasture legumes are now being investi-

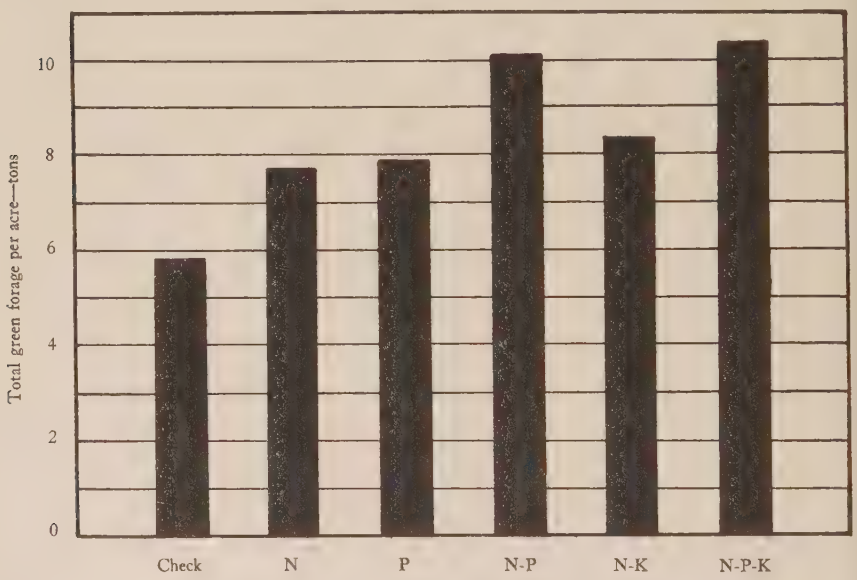


Figure 14.—Response of a Kikuyu-grass pasture to nitrogen, phosphorus, and potassium in a high-rainfall area in windward Oahu. Results given as tons of green forage per acre, average of 3 crops. Amounts of fertilizer per acre per year: N is equivalent to 100 pounds of nitrogen as ammonium sulfate; P is equivalent to 200 pounds of phosphorus pentoxide as superphosphate; K is equivalent to 100 pounds potassium oxide as potassium sulfate.

Figure 15.—Kaimi Spanish clover *(Desmodium canum)* is a promising legume in wet lowland pastures. Left: It spreads and persists among other forage grasses. Here it is shown growing in a pasture of Kikuyu grass. Right: It has a large shallow root system. The ruler in the picture is 6 inches long.

gated by mapping present distribution and relative abundance of 36 important species. The vegetation zones previously described are helpful, but it is apparent that for raising legumes a knowledge of localized factors of climate and soil is necessary. Twenty legumes most likely to be adapted were planted in four different zones, ranging in rainfall from 40 to 100 inches per annum, and in altitude from 1,200 to 6,000 feet. At each location the planted rows were cross-stripped with lime and phosphates. Parts of each plot of each legume were treated with the appropriate nodule inoculum. Preliminary results indicate that fertilization may be very important in establishing legumes in pastures. *(Ripperton, Hosaka)*

Ecological Study of Desmodium canum

The possible importance of the recently identified legume, Kaimi Spanish clover *(Desmodium canum),* in wet, lowland pastures has already been mentioned. The growth habits of the plant in pastures, in cultivated plots, and in special boxes constructed for determining root distribution, have been observed. It has a large root system, but the roots are shallow and the tap root very short, indicating that the plant may be susceptible to drought. When uncut, the plant develops strong, upright stems with elliptical leaflets resembling those of ordinary Spanish clover. When the plant is cut or trampled, a strong growth of decumbent or prostrate stems develops, and this growth roots at the nodes. The leaflets on this type of stem are small and rounded, so that at a distance the plant resembles white clover. By means of these decumbent stems the plant spreads rapidly; a single plant in a pasture sometimes attains a spread of 15 feet or more in a few seasons. *(Hosaka)*

SWEET CORN

Mass selection of the U.S.D.A.-34 sweet corn, after five generations, has eliminated in large part such undesirable characters as red cob, pseudo-starchiness, crooked rows, and bent tassels, so that now, under normal conditions of growth, fairly uniform ears of high quality are produced.

In the absence of a commercial source of high-quality seed, most growers save their own. As proper attention is not given to selection, in most instances the variety soon deteriorates almost beyond recognition. To improve the situation, this station cooperated in making available to growers, through a local seed firm, 2,740 pounds of selected seed produced in the following manner: the station's best seeds were planted in the field of a local grower; the field was rogued twice (in cooperation with the University of Hawaii extension service); and final selection of the seeds was made after drying the ear corn.

In the station's sweet-corn breeding project, a total of 75 selfed lines of U.S.D.A.-34 and 50 backcrosses of U.S.D.A.-34 and mainland varieties were carried through two additional generations. Several inbred lines selected for tender pericarp have been carried through four generations and appear to breed true for this character. They are tested for pericarp tenderness with a puncture apparatus similiar to that recommended by Culpepper and Magoon. *(Takahashi, Hodges)*

Vegetation Zones

Based upon climatic data and upon surveys of occurrence and distribution of plants in pasture areas in the Territory, the land mass of the principal islands of the Territory has been classified into zones such as were described in 1939. The influence of climates on vegetation in the different zones is well illustrated by the relative numbers of species found in pasture areas.

Of the 316 species listed, 150 were found in Zone B. The relatively low seasonal rainfall in this zone (20-40 inches annually) is conducive to growth and seeding of numerous annual herbs and grasses. Zones C_1 and C_2, with annual rainfalls of 40 to 60 inches, were next in numbers of species, with 142 and 144 respectively. Zone A, with less than 20 inches annually, has only 59 species. Zone D_2, with ample, often excessive rainfall, had only 56, most of which were perennial, and Zone E_1, which is both cold and dry, had only 24 species.

Frequency and length of dry periods would, of course, be closely related to total rainfall. Considering a calendar month with less than 1 inch of rain as "dry," rainfall records of 24 stations for the period 1907-38 showed that at stations with a normal rainfall of 60 inches or more (the division

between Zones C and D), there were no dry months; at stations with 40 inches annually (the division between Zones B and C), 20 percent of all months may be dry; at stations with 20 inches annually (the division between Zones A and B), the expectation is for 60 percent of all months to be dry. As to length of dry periods, stations with 40 inches or more of rain a year had no periods longer than 3 months; at 20 inches, periods of more than 3 months accounted for 80 percent of all dry months.[2]

The occurrence of dry periods is undoubtedly significant in reproduction of annual species in pastures. In Zone D_3 the seeds of such species as rescue grass *(Bromus catharticus),* black medic clover *(Medicago lupulina),* and bur clover *(Medicago hispida)* do not cure properly or tend to decay before they germinate. In Zones A, B, and C, the annual species reseed readily. The seasonal fluctuation in herbage is, of course, greater in dry than in wet zones.

The seed reserve in the soil is of practical interest to the rancher. Obviously, if no seed of a species is present in the soil, resting the paddock would be of no avail in increasing the species, and reseeding would be necessary. Conversely, if ample seeds are present and growth is diminished by heavy grazing, resting would suffice, although where the sod is dense, plowing may be necessary. In any event, a knowledge of the seed reserve is desirable. Experiments are in progress to determine seed reserves in soil samples from pastures in different zones; when completed, they will provide further evidence of the hypothesis set forth above. *(Hosaka, Ripperton)*

FRUITS AND NUTS

MACADAMIA

Nursery Propagation

That successful grafting of macadamias is dependent on the amount of starch stored in the scion was demonstrated several years ago. Ringing the branch intended for scion wood will stimulate starch storage, although not always at the same rate. Of nine mature seedlings tested since the 1940 report, one developed abundant starch within 2 weeks and five more had ample reserves after 4 weeks, but 8 weeks had elapsed before scion wood was available from all nine trees.

Removing a small portion of the macadamia branch and testing for starch by the iodine method is recommended for successful propagation, since the time element is so variable. *(Jones)*

[2] These data were calculated by Dr. S. B. Jones, Assistant Professor of Geography, University of Hawaii.

Germination

Macadamia nuts begin to germinate within a few days after dropping to the ground if there is adequate moisture. For this reason all nuts should be harvested promptly in order that their quality may be preserved.

As the nuts germinate, the oil reserves are rapidly depleted. Samples of embryos gave an average value of 2,326 milligrams of oil at beginning of germination and only 387 milligrams after 6 weeks. A large part of this oil was used in growth of the young plant, and a small amount accumulated as soluble materials in the cotyledons. This soluble material, which includes sucrose and reducing sugars, was 237 milligrams per embryo at the beginning of germination and 525 milligrams after 6 weeks. Starch, which was not found in the resting embryo or during development, was formed in the cotyledons during germination in the dark, reaching a peak of 93 milligrams per embryo. *(Shaw, Jones)*

Varieties and Selections

Some 4,000 grafted trees, representing about 80 individual tree selections, are now included in the various cultural and variety test orchards on Hawaii, Maui, Kauai, and Oahu. Only one promising new selection, a tree growing at Grove Farm on Kauai, has been found recently, but several young seedling orchards are coming into bearing and will be surveyed for outstanding types. *(Storey)*

PAPAYA

Inbred Lines

Progenies of 26 self-fertilized hermaphrodite Solo papaya trees, selected in commercial plantations for fruit quality, shape, and size, fruited during 1941 and 1942 in plantings at Koko Head, Waiau, Kunia, Waipahu, and Poamoho. Close comparison of all of the lines at the various orchards was not possible because growth and production were greatly retarded by unseasonably dry weather. Normal growth was maintained only at Poamoho, where the plantation was situated on irrigable land.

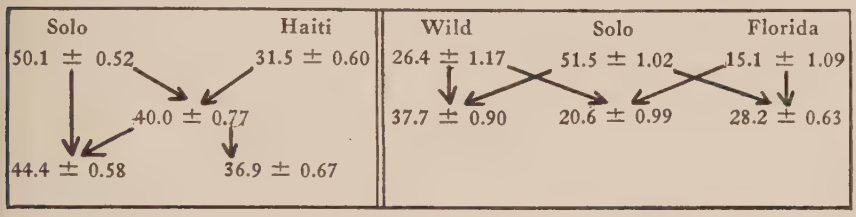
Only six of the selections seemed to be of sufficient merit to warrant continuance of their lines. The second generations of these lines are now approaching maturity at the Poamoho Experimental Farm. *(Storey)*

Inheritance Studies

Most commercial strains of the Solo papaya set their initial fruit crops at a height of at least 4 feet above the ground and require 14 months or longer from germination of the seed to come into bearing. Under conditions suitable for good growth and production, the trees reach such heights by the

end of the second bearing year that harvesting is a troublesome problem. Breeding work has been in progress, therefore, to combine the dwarfness and early maturity of certain strains of papaya with the quality of the Solo strain.

The effects of reciprocal crosses among inbred lines of the Solo strain, the Haiti, an accession from Florida, and the so-called wild papaya from the Canal Zone on mean heights (in inches) of initially fruiting axils are illustrated below:



In every case the average height of each set of first-generation hybrids was intermediate to the heights of the parental lines involved, and closely approximated the arithmetic average height between the two parental lines. Sex of the parental lines represented did not appear to affect height of the first flowering axils.

Data on the second-generation progeny and on a backcross are available only for the Solo-Haiti cross. The difference between the means of the first and second generations in this cross is not considered significant, because weather conditions were less favorable for growth in the second period. The backcross of the first-generation hybrid with the Solo parent yielded a progeny intermediate in fruiting height between the two; there was no evidence of segregation into two distinct classes.

It appears from the study to date that multiple factors are involved in the inheritance of fruiting height and that one can expect the product of any cross to be intermediate to the parents. *(Storey)*

Accessions and Selections

Only three accessions of papaya seed, all of them from the Canal Zone, were successfully introduced from outside sources during the biennium.

Twenty-two accessions that were received previously fruited in the variety planting at Poamoho. Among the few that seemed worthy of retention for breeding purposes are "Fairchild," a red-fleshed strain from Florida; "Florida," a low-bearing, early-maturing strain from Florida; a large-fruited, red-fleshed strain from South Africa which yielded a larger quantity of latex than other strains; a strain from Java whose hermaphroditic fruits,

slightly larger than Solo, have thick flesh, good flavor, and a very regular cavity; and the so-called "wild" papaya from Florida, which seems to be fairly resistant to powdery mildew. *(Storey)*

Study of Carpellody

Carpellody in the papaya is the tendency of the stamens at certain seasons to assume the structure and functions of carpels, which may be fused in various degrees with the main pistil. Carpellody generally results in malformed fruit. At some seasons and in some strains the proportion of misshapen fruit may approach 100 percent.

At this writing it appears that the occurrence of carpellody depends upon a set of genetical factors whose expression is influenced both by environment and by flower structure. Hermaphrodite trees possessing this set of factors may produce carpelloid fruits at one season and no carpelloid fruits at another season. Or carpelloid fruits may be produced from flowers in a terminal position on the peduncle and not from flowers occupying lateral positions, or vice versa. Bisexual functionability within the flower, that is, functionability of both ovary and stamens, seems to be a prerequisite for the expression of the trait.

Twenty-one individual tree selections were made in previous years for the study of carpellody. Recent observations on their progenies have revealed that if carpellody is present in the parent tree, regardless of the degree to which it is expressed, all of the hermaphroditic offsprings exhibit the trait. Some of the parent selections were trees whose crops contained less than 1 percent carpelloid fruits, yet individual offsprings contained up to 100 percent at some seasons.

This investigation is being continued with a series of interlocking crosses and backcrosses among carpelloid form-B hermaphrodites and an apparently carpellody-free form-C hermaphrodite. In addition to testing an earlier observation that there is negative correlation between the tendency of a tree to bear carpelloid fruits and the tendency of the tree to form type IV+ flowers, such a series of crosses may throw light on the genetics of that trait and be of use in breeding work. *(Storey)*

Colchicine Experiments

Experiments with colchicine and colchicine-induced polyploid trees of the papaya have been continued in an effort to establish polyploid and aneuploid lines for the genetical study of certain plant and fruit characters and for breeding. Polyploid stems growing upon diploid roots were easily obtained by treating the growing points of seedlings in the cotyledon stage with 25 to 30 drops of 0.4 percent colchicine in aqueous solution over a 2- to

3-day period. Although treated stems continued on to fruiting and some of the fruits had seeds, no polyploid seedlings have yet been obtained. The seeds either failed to germinate or produced diploid plants.

Quantitative increase in chromosome number does not seem to affect sexual expression but is manifested in other ways. As compared with diploid plants, the leaves are generally slightly larger and with thicker blades, the flower stems are shorter and stouter, the flowers are slightly larger, and the fruits are smaller and foreshortened. There seems to be a greater disposition on the part of the polyploid female to set parthenocarpic fruits than on the part of the diploid female. Some of the trees exhibit unusual plant characters, such as curled leaf margins and large, droopy leaves. One tree proved to be a periclinal chimera with polyploidal tissues underlying the diploid epidermis. *(Hartung, Storey)*

Photoperiod

As has been pointed out, many hermaphrodite papaya trees cease to set fruit during the summer. The long photoperiod favors the production of staminate flower parts and suppresses the development of pistillate flower parts. Under a controlled long photoperiod (18 hours) the results shown in table 23 were secured for hermaphrodite plants.

Table 23.—Influence of photoperiod on growth of papaya trees

	Photoperiod	
	Normal	Long
Number of trees	15.0	14.0
Number of fruit per tree	11.7	3.8
Average height of trees in feet	5.7	7.5

Under the long photoperiod some trees (form B) continued to fruit; seed from these fruiting plants yielded continuously fertile hermaphrodite trees. *(Jones, Ikeda)*

Culture Notes

Experiments at Poamoho have shown that both phosphorus and nitrogen are needed for best growth and yield of papayas, although recommendations as to quantity cannot yet be made. At this location it proved inadvisable to space trees closer than 8 feet within the row and 10 feet between rows. *(Jones, Ikeda)*

Diseases and Control

Spraying. Papaya plants sprayed with Bordeaux mixture showed severe injury, as they had when so treated in the period covered by the last previ-

ous report. Especially the young foliage was severely injured, and fruits developed russetting and scabbiness. Cuprous oxide did not appear to injure plants in the prescribed dosage (yellow form, 1½ pounds per 100 gal.; red form, 3 pounds per 100 gal.). Spraying with sulfur produced no injury and controlled mildew *(Oidium* sp.) effectively. *(Kikuta)*

Anthracnose. Papaya anthracnose, caused by *Colletotrichum* sp. (probably *C. gloeosporioides)* appears on immature fruits only when they are treated with methyl bromide for control of the Mediterranean fruitfly *(Ceratitis capitata),* or when they are kept under an anaerobic condition for several days. Detached green papaya fruits, held at 95 to 100 percent relative humidity and artificially inoculated with the fungus spores, develop anthracnose within 5 to 10 days. *(Matsuura, Parris, Jones)*

Virus disease. The papaya-virus disease, which appeared in an epiphytotic condition in 1937, has occurred in only a few places during the past 2 years. This finding seems to correspond with the low degree of disease transmission through mechanical abrasion. Transmission of papaya virus through dodder *(Cuscuta* sp.) has been negative, probably because of the inability of the dodder to establish itself or to parasitize the papaya plant. *(Matsuura)*

Damping-off control. Chloropicrin, which is used in the control of nematodes, was very effective against the damping-off caused by *Rhizoctonia* sp. and *Pythium aphanidermatum* on papaya. It did not, however, control subsequent infection. Table 24 illustrates the benefit derived from application of chloropicrin at the rate of 6 cubic centimeters per cubic foot. *(Matsuura)*

Table 24.—Damping-off of papaya, caused by *Rhizoctonia* sp. and by *Pythium aphanidermatum,* and its control by chloropicrin

Treatments	Total emergence	Post-emergence damping-off	Final stand
	Percent	*Percent*	*Percent*
Check	71	0	71
Rhizoctonia	58	53	5
Rhizoctonia-chloropicrin	80	[1]3	77
Pythium	51	30	21
Pythium-chloropicrin	82	0	82
Pythium-chloropicrin-*Pythium*	9	8	1

[1] Insect larvae responsible.

MANGO

Varieties

Three mango orchards at the Pensacola site now aggregate 221 trees. The first of these orchards was planted in the period from 1907 to 1911; the

second was planted in 1923, and the third, in 1938. All of the 41 clonal varieties in the station's collection are represented by one or more trees in the Pensacola orchards.

There is one orchard of 69 trees at Poamoho Experimental Farm, planted in 1940. It contains at least 2 trees each of the 18 varieties selected as best for Hawaii. A few of the trees blossomed in the spring of 1942, but because of unfavorable weather they set a very light crop.

In order to provide a large number of trees for a cultural orchard at Poamoho, propagation of the mango, particularly the varieties Haden and Pirie, is continuing. Data on the cultural, fertilizer, and irrigation requirements of the mango, and also on quality and commercial possibilities of varieties, are urgently needed, since commercial orchards are already being developed on the Islands of Maui, Oahu, and Kauai.

Many of the more recently introduced varieties which are highly recommended for planting in other countries have proved generally inferior under Hawaiian conditions to varieties already established. The Pirie and Haden varieties continue to be favored both by consumer and grower, and serve as the standards by which all other varieties must be judged. *(Storey)*

Methyl-Bromide Treatment

Effective August 1, 1940, the quarantine laws were modified so that several Hawaiian fruits, including the papaya, could be exported after fumigation for 3½ hours, at or above 80° F., with 2 pounds of methyl bromide per 1,000 cubic feet of space. During such a treatment the papaya absorbs about 27 to 30 milligrams of methyl bromide per kilogram of fruit. This absorbed methyl bromide retards the rate of ripening and greatly increases the percentage of decay in firm-ripe and mature-green fruit. For these reasons methyl bromide is not recommended for treatment of papayas. *(Jones, Ikeda)*

Waxing

Waxing reduces the water loss from papayas during storage and ripening and consequently improves the appearance of the fruit. Unwaxed fruits lost 2.7 percent water during 6 days of storage at 50° F. and a total of 4.8 percent during storage and subsequent ripening. The corresponding figures for waxed fruit were 0.3 and 1.8 percent.

Quality

Quality in papaya has been considered largely a matter of personal preference, dependent on a variety of factors, such as color, flavor, texture, aroma, and sweetness. However, a recent taste test has established rather concretely a relationship between quality and sugar content of the fruit. A

group of tasters judging 16 individual fruits as poor, good, or excellent, agreed on placement of each fruit into one of the three groups. The sugar contents of the individual fruits (expressed as percentage of fresh weight) are shown below:

Poor fruits	Good fruits	Excellent fruits
Percent	*Percent*	*Percent*
6.9	10.4	12.0
7.2	10.7	12.3
7.6	10.9	12.5
8.3	11.3	13.3
8.7	11.9	14.5
8.9		

Since quality is correlated with sugar content in the papaya, the question arises as to what factor or factors bring about high sugar values. Sunlight, mineral nutrition, and water are important, but the most easily measured factor under a given set of environmental conditions is the ratio between fruits and leaves on each individual tree. Within the orchard the number of leaves per tree and the number of fruits per tree vary widely. The individual tree with the largest number of leaves in relation to the number of fruits bears fruits with the highest sugar content and consequently of the highest quality. A correlation coefficient of —0.88 for Poamoho and —0.74 for Ewa has been found between the number of fruits per leaf and the sugar content.

The question that then arises is how to maintain a low fruit-leaf ratio. This can be done in part by keeping the leaves free of mildew, supplying adequate water and mineral nutrients, and removing all cull fruits while they are still young. Further work is being done on this problem. *(Jones, Shaw, Ikeda)*

Quick Freezing

That the mango can be successfully quick-frozen has been demonstrated in trials made in the freezing compartment of a household-type electric refrigerator, at temperatures between —8° and 0° F. Probably even better results will be obtained when more suitable equipment becomes available. The Pirie mango was frozen in the following ways: dry, dry and wrapped in cellophane, and in 30- and 40-percent sucrose solutions. The texture of the dry-frozen material was poor after thawing. Both texture and flavor of the material frozen in 30-percent and in 40-percent sucrose were good; however, fruits frozen in 40-percent sucrose became slightly too sweet. The Haden and the Cowasjee Patel varieties were also successfully quick-frozen. There was a slight loss of color and texture in the Mulgoba and Wootten. *(Jones)*

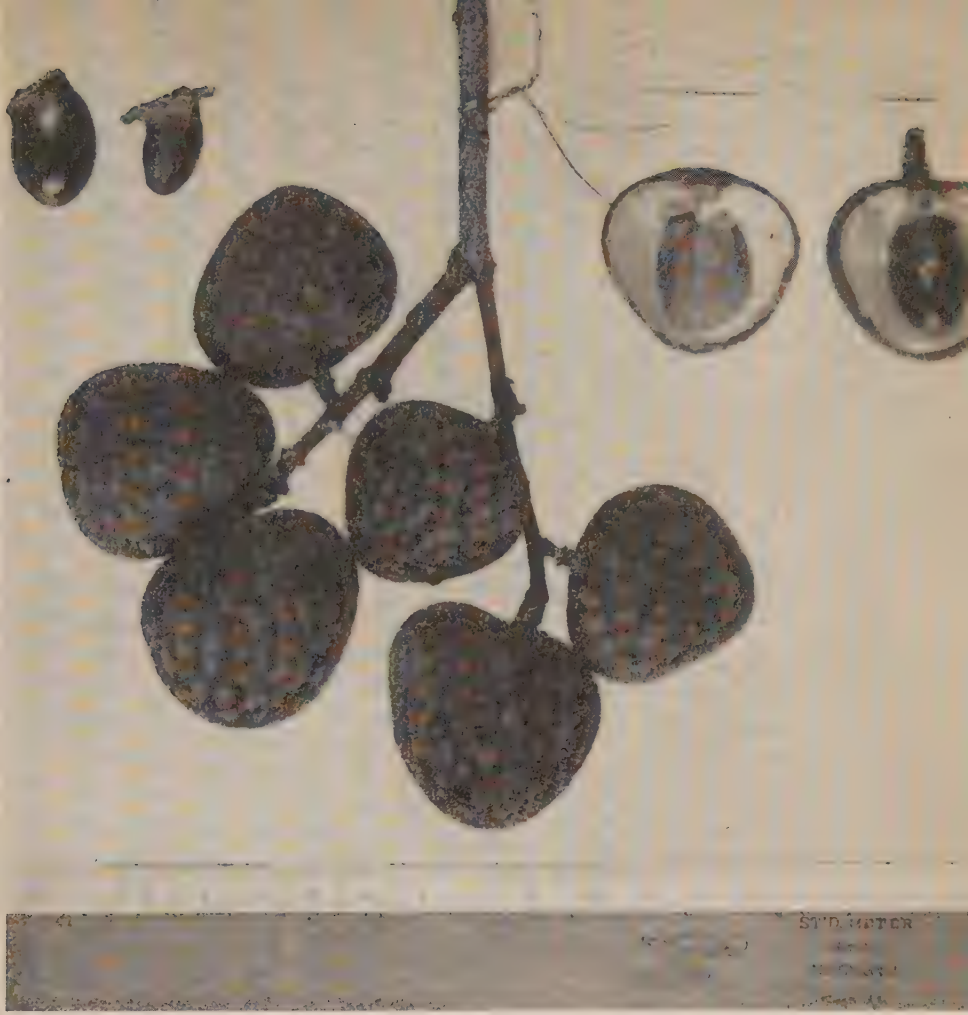


Figure 16.—Fruits of the litchi variety, Pak lap lai chi, which fruited in 1941 for the first time since its introduction into the Maui orchard of Collaborator D. T. Fleming.

LITCHI AND LONGAN

The litchi collection at the station has been augmented by various new accessions and introductions and now comprises trees of the following 14 varieties:[3] Kwai mi, Hak ip, Wai chi, Heung lai, Kwa luk, Tai tso, Fi tsz siu, Chong un hung, No mai t'sz, Pat po hung, Pak lap lai chi, Tim ngam, Shan chi, and Hanoi. Several of the varieties were introduced from different magistracies in South China and reveal clonal variations. Many of the trees are of fairly recent introduction and are small, but the varieties are being propagated as rapidly as possible for the establishment of a variety orchard at Poamoho.

[3] Excepting "Hanoi," which the station received from French Indo-China through the courtesy of Mr. D. T. Fleming of Lahaina, Maui, the varietal names given are in the Cantonese dialect under which most of them were received. See: GROFF, G. WEIDMAN, THE LYCHEE AND LUNGAN, APPENDIX IV, P. 143, 1921.

The variety Shan chi has recently been introduced and may prove to be a worthy addition to the varieties in Hawaii for use as a rootstock for grafting. It is the preferred rootstock in China, particularly for trees to be grown in upland culture. There are few dyke-planted trees and no dyke-planted orchards in Hawaii.

During the past two fruiting seasons, trees of the Kwai mi and Hak ip varieties produced fair crops in most of the localities in which they were planted. Unseasonably dry and windy weather during the seasons of flowering, and early fruit development undoubtedly reduced the potential yield. Judging from bagging experiments and from observations of weather conditions in several locations, it would seem that low atmospheric humidity and lack of rain during and following the flowering season is detrimental to the setting and maturing of a heavy crop.

In 1941 the variety Pak lap lai chi fruited for the first time since its introduction, in the orchard of D. T. Fleming at Honokohau, Maui. The fruit (fig. 16) is large in comparison with other varieties and is of good quality.

The variety Wai chi, although it has been in Hawaii since 1918, has never been reported in fruit prior to this year. One tree at Aiea, Oahu, was flowering and setting a crop of fruit in May 1942, and another tree on Kauai is reported in flower. Fruits of this variety are not yet available.

Approximately 300 branches on trees of the variety Kwai mi have been air layered for planting in a cultural test orchard at Poamoho. Factual data on litchi culture will become more and more essential as the several large commercial orchards on Maui, Kauai, and Oahu continue to develop. In the meantime a seedling orchard of approximately 500 trees has been planted at Poamoho. Most of the seeds were obtained from the variety Kwai mi, but the variation among seedlings is so great that one must conclude that this variety and other varieties as well are heterozygous for many characters. On this premise, the fruiting of seedlings might well yield desirable and promising types for Hawaii. The work of recording and cataloging tree and fruit characters is continuing and being augmented as various accessions come into bearing.

After a very dry summer in 1941 followed by good rains in the first months of 1942, almost every longan tree in the city has come into bloom, some of them for the first time in many years. It is yet too early to determine what kind of crop will set. It is perhaps noteworthy that a protracted dry season followed by rains has brought the trees into flower when various branch-girdling and root-pruning experiments have failed.

AVOCADO

Work has been in progress during the past 2 years on the compilation of a check list of avocado varieties in Hawaii. Principal attention is being given to those varieties that are grown in commercial orchards for the retail trade, but the better varieties of common occurrence in home gardens are also being included.

Since the appearance of the last publication on the avocado in Hawaii in 1924,[4] many varieties of local origin have been displaced in local markets by varieties of the "Popenoe collection,"[5] and by subsequent introductions. Meanwhile, information has been accumulating on plant and fruit characters, fruiting periods in Hawaii, and the influence of elevation on growth. The performance of 36 varieties has been surveyed for the fruiting seasons of 1940-41 and 1941-42.

Representative varieties of the three races of the avocado—Guatemalan, Mexican, and West Indian—and of hybrids among the races have been planted in an orchard at Poamoho. At least 2 trees each of 19 varieties are represented. These were so selected that one or more of them will be in production at any given time between July 1 of one year and April 30 of the year following.

A constant lookout has been kept for trees that produce good crops of quality fruit during May and June, the months in Hawaii in which avocado production falls away to almost nothing. Two promising seedling trees, one of the West Indian race, the other very probably a Guatemalan-West Indian hybrid, have been discovered. These trees produce fruits of good quality and are said to be fairly consistent in maturing their crops in May and early June. Grafted trees of these seedlings have been planted in the variety orchard at Poamoho for further observation. *(Storey)*

CITRUS FRUITS

Since entry of America into the war, there has been a resurgence of interest in the growing of citrus fruits in the home garden, because limitations on importation of citrus fruits from the Mainland have created shortages of oranges, lemons, and grapefruits in Hawaii.

Observations on the culture of citrus fruits during the past 40 years have shown that lemons and limes are well adapted to Hawaiian conditions. Grapefruits and oranges, although they do not generally attain the quality and attractiveness of mainland-grown fruits, can be grown in many favorable locations and made to produce large crops. The Hawaiian orange

[4] POPE, W. T., THE GUATEMALAN AVOCADO IN HAWAII. Haw. Agr. Expt. Sta. Bul. 51; 24 pp. 1924.

[5] *cf.* HAW. AGR. EXPT. STA. ANN. RPT. 1919; p. 30.

grows and yields well in most locations and is an excellent source of juice.

The station has maintained a citrus variety orchard at its Pensacola site since 1901. All of the proven varieties in this orchard are being grafted to vigorous shaddock and sour-orange rootstocks for the establishment of a variety and cultural orchard at Poamoho. The soil at Pensacola is too heavy and drains too poorly for the best development of a citrus orchard, and irrigation facilities have not always been adequate. *(Storey)*

COFFEE

In order to establish indices for fertilizing and cultivating coffee orchards, data were obtained on leaf samples collected at monthly intervals for 18 months from 10 selected trees on each of 30 farms scattered throughout the Kona belt, and also from selected plots of differential fertilizer experiments. The samples, which were all of comparable physiological development, were analyzed in the laboratory for total and nitrate nitrogen, potash, carbohydrates, and moisture. Following is a summary of the findings to date:

(a) As coffee leaves increase in age, there is a gradual decrease in the amounts of potash in the leaves. This decrease is only slightly affected by fertilizer applications during the life of the leaves.

(b) Leaves developed during the current spring should have from 2.0 to 2.5 percent of potash (dry basis) in July. This percentage should drop to 1.5 or slightly lower during the fall harvest season.

(c) In general, dieback—a diseased condition of the tree in which the terminal twigs are blighted—is severe when the tree yield is high. However, on certain farms where heavy applications of complete fertilizer have been made during the early spring, dieback has been low despite heavy crops. When the potash content of the leaves falls below the indices given above, severe dieback almost always occurs.

(d) Within a given coffee orchard, selected trees showing a marked degree of dieback had significantly lower percentages of potash in their leaves than trees showing only a slight degree of dieback.

(e) The optimum range in total nitrogen for coffee leaves is from 2.5 to 2 percent (dry basis). The leaf nitrogen content is readily altered by the application of nitrogenous fertilizer materials; following a dry period the leaf nitrogen increases, presumably as a result of increased amounts of available soil nitrogen.

(f) A significant correlation was found between leaf color and percentage of total nitrogen in the leaves—the darker the green of the leaves, the higher the nitrogen content.

(g) Relatively high amounts of nitrate nitrogen (0.03-0.10 percent) were found in leaves 2 to 10 months in age. Older leaves contained comparatively smaller amounts. The percentage of nitrate nitrogen in leaves of trees from the same orchard may show considerable variation from month to month. The significance of the high and varying nitrate-nitrogen content of coffee leaves has not been ascertained.

(h) Coffee leaves show a distinct accumulation of carbohydrates during the winter dry season and a sharp decline as spring growth develops. A much more marked accumulation occurs in trees grown at high elevations. *(Dean, Beaumont)*

TOMATOES

Methyl-Bromide Treatment

Tomatoes, like papayas, absorb small quantities of methyl bromide when treated according to quarantine regulations. For tomatoes this amounts to from 30 to 35 milligrams per kilogram of fruit. The percentage of decay is also increased in mature-green tomatoes, although it is usually well under 10 percent. For instance, one lot of treated fruits showed 6.9 percent decay as compared to 3.1 percent for untreated fruits.

It has been found necessary to hold methyl-bromide-treated fruits at room temperature for at least 24 hours before storing at 50° F. One lot of fruits showed 52 percent decay when placed in cold storage immediately after treatment; a comparable lot showed only 8 percent decay when held 24 hours at room temperature before storage.

Several trial lots of tomatoes were shipped to the coast to compare methyl-bromide treatment with vapor-heat treatment. There was slightly more decay and a slower rate of ripening in the methyl-bromide-treated fruits. *(Jones)*

Waxing

Mature-green tomatoes lose water and become shrivelled under conditions necessary for coast shipment. This can be prevented, in part, by waxing. The use of Brytene wax 284-D reduced the water loss from the 3.1 percent that occurred in check lots to 2.4 percent. The waxed fruits were less shrivelled than the unwaxed fruits. *(Jones)*

Introductions

Plants introduced by the horticulture division during the past biennium are listed in table 25.

Table 25.—Plant introductions during the biennium ending June 30, 1942

Scientific name	Number of varieties	Source	Type of material
Annona diversifolia	1	Tela, Honduras (through W. Popenoe)	Seed
Carica papaya	3	Summit, C. Z. (from W. Lindsay)	Seed
Citrus limonia	1	Florida (through U.S. D.A., B.P.I., Washington, D.C.)	Scions
Dipteryx odorata	1	Port-of-Spain, Trinidad, B.W.I. (from Director Williams, Agr. Dept.)	Seed
Garcinia mangostana	1	Manila, P.I. (through B.P.I.)	Seed
Lansium domesticum	1	do	Seed
Litchi chinensis	6	Canton, China (through G. W. Groff)	Scions, grafts, air layers
Mangifera indica	1	Manila, P. I. (through D. T. Fleming)	Scions
Nephelium mutabile	1	Singapore (through D. T. Fleming)	Seeds

VEGETABLE CROPS AND DISEASES

Vegetable crops constitute a large and extremely varied group of plants which are consumed directly by the human race. As a group they are important because they add minerals and vitamins to the diet, and provide diversity and flavor. Most vegetables are highly perishable but may be canned, frozen, dried, or otherwise processed, thus materially enlarging their distribution. The processed vegetable is, however, normally quite different from the fresh product. The frozen vegetable is more nearly comparable, but not all fresh vegetables can or should be frozen. In no case has the processed vegetable replaced the demand and need for the fresh product.

Under war conditions in Hawaii, when limited and irregular shipping makes it difficult to maintain supplies even of staple foods, the problems of maintaining supplies of fresh, perishable vegetables are multiplied many fold. In fact, assured supplies are coming only from local production, which, however, in pre-war times provided only a small percentage of total local consumption. The problem is now enhanced by a large increase in population on Oahu and the fact that inter-island shipping, interrupted by the war, has not been restored. Thus the demand is on Oahu, whereas the larger

supplies, the greater proportion of the farmers, and the more suitable vegetable lands are on the outside islands.

The first World War, the depression, and the shipping strike of 1936-37 emphasized the great need for local production of foods, particularly vegetables, fruits, milk, and meat. Although many of the problems that have arisen in the present situation are beyond control of the producer and could not have been foreseen, nevertheless, the basic material for surmounting the difficulties—information on problems and cultural practices in large-scale production of perishable vegetables—has greatly advanced over that available in earlier emergencies.

Commercial vegetable growing in the Territory has been a small-farmer enterprise, localized generally into districts. Each district is characterized by its own soils, climate, and crops. Production is almost exclusively for the fresh market. Even though seasonal influences in Hawaii are minimized by the subtropical, insular climate, they are nevertheless of sufficient importance in vegetable growing to multiply the number of problems. In addition, there are problems incident to large-scale production, necessitated by the war, on lands not previously in vegetables.

The immense amount of information on varieties, cultural practices, fertilization, and diseases accumulated over the past years has been made available to growers by this station and the University of Hawaii extension service through publications, demonstrations, lectures, and personal associations. The following brief resume can only indicate the nature and extent of the work which is now being applied so widely.

Taken in conjunction with preceding reports of the station, these condensed statements of the work with vegetable crops serve to indicate some of the technical problems involved.

FERTILIZER-PLACEMENT AND SEEDING MACHINERY

Anticipating emergency demands for increased production of vegetables, authorities recognized that one of the first and most important considerations was the development and employment of labor-saving devices adapted to Hawaiian soil and irrigation practices. The trustees of the Hawaiian Sugar Planters' Association, on the recommendation of the Diversified Crops Committee of that organization, purchased a number of machines in 1941 for experimentation and adaptation by the truck-crop division of this station and by plantation agriculturists. These machines included a small tractor with seeder and many types of cultivation attachments, a transplanter, and materials to construct a 4-row sled planter with fertilizer-placement equipment. The latter was constructed under the supervision of

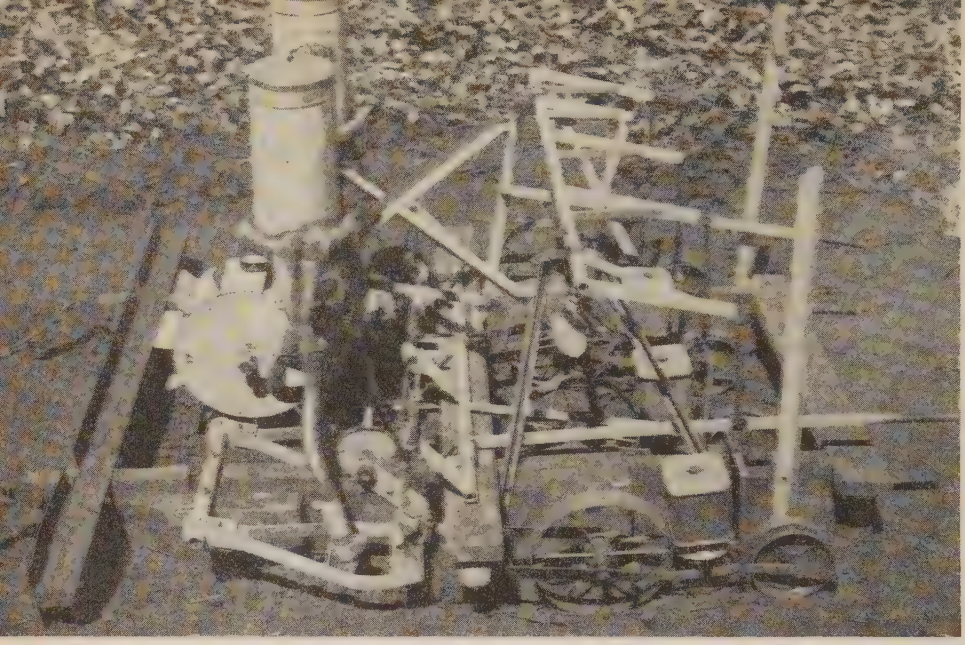


Figure 17.—Four-row sled planter, with fertilizer-placement equipment, which was constructed locally and has proved very satisfactory in raised-bed, furrow-irrigated culture as well as in flat-bed, overhead-irrigated culture.

the truck-crop division by a local shop and has proved very satisfactory for seeding and fertilization in both furrow-irrigated, raised-bed culture and overhead-irrigated, flat culture. This machine places the fertilizer in a band to a depth of 2 to 4 inches and slightly to the side of the seed (fig. 17).

On the red, upland soil at Poamoho it was demonstrated that such crops as onions, carrots, beets, cabbages, and turnips could be planted satisfactorily by mechanical means in two-row, raised beds. Water penetrated laterally from the furrow to the seeded row at grades of about 0.2 percent, so that this method is practical only on rather level, well laid-out fields.

Observation and trial of these machines made it possible to formulate a large order for agricultural machinery by the Army immediately after the outbreak of the war. The machines are serving admirably in furthering the food-production program. *(Frazier)*

BEANS

Varietal Studies

Bush green. Long Island Long Pod, Tenderpod, and Streamliner are new varieties that have been added to the long list given limited trial for adaptation to Hawaiian conditions. Bountiful, Plentiful, Giant Stringless Green Pod, Burpee Stringless Green Pod, and Asgrow Stringless Green Pod continue to perform well. U.S.D.A. Refugee No. 5 has given good

yields, but pods are small and require more time for picking. The Bountiful, Plentiful, and Giant Stringless Green Pod are now being grown extensively and constitute a large portion of the acreage in food crops.

Pole green. Hybrids of Lualualei, Kentucky Wonder, Kabuto, and other pole beans have been obtained, as well as hybrids with bush varieties. In spite of susceptibility to rust, Lualualei remains the most widely planted variety because of its flat pods and good market appearance. Breeding of pole beans for disease resistance and market quality is of principal interest to the small farmer, as these types are not adapted to field culture.

Pole lima. Probably no vegetable crop is more admirably adapted to the Hawaiian climate than the bush and pole limas. Of the large-pod, pole varieties, Fordhook Pole has repeatedly given high yields over periods of several months. King of the Garden has not set as many pods as Fordhook Pole, although its performance has been satisfactory. Burpee Best has given good results. Of the small-pod, pole varieties, Carolina Sieva and Florida Speckled have been extremely prolific.

Bush lima. Tests of bush-lima varieties have been made repeatedly at both Poamoho and the University. Recent trials included Fordhook Bush, No. 8 Cambell Hopi, Fat Baby Bush, Early Baby Potato, Henderson Bush, Baby Potato, and U. S. Baby Fordhook. Baby Potato has rather consistently outyielded Henderson and most other small-seeded types. Fat Baby Bush, not available commercially, has given as good yields as Baby Potato. These findings have been applied on a large scale since the war, both in ordering seed and in extensive field plantings.

Especially the Fordhook Bush, a large-podded, green-shell bean, has been planted in large acreages for war food production. It has performed well, in both winter and summer, on the Island of Oahu.

In fertilizer trials the lima beans have responded to heavy phosphate fertilization on the upland, red-brown soil at Poamoho Experimental Farm. *(Tachibana, Frazier)*

Bean Rust

In the 1938 annual report of this station the presence in Hawaii of the bean rust fungus, *Uromyces phaseoli typica,* was reported. Four bean varieties, introduced from mainland United States, were recommended to growers as substitutes for the widely grown but highly susceptible local variety Lualualei. In the 1939 annual report, mention was made that a different rust strain was present, evidenced by the susceptibility or lowered resistance of bean varieties formerly not affected by rust. The four varieties mentioned above were fortunately not affected by this second strain. Early in 1941, a third strain of rust appeared, to which the four recommended sub-

stitutes for Lualualei are more or less susceptible. Other varieties, never previously attacked, are either highly susceptible or but slightly resistant. Lima beans continue to exhibit marked resistance.

Numerous crosses are being made between the high-yielding, susceptible and the resistant, but low-yielding beans with the hope of obtaining high-yielding, rust-resistant types. *(Matsuura, Parris)*

BEETS

An observational test of five varieties of "table" beets, selected on the basis of previous performance, was planted at Poamoho on raised, irrigated beds on November 11, 1941. These were: Green Top Bunching, Asgrow Wonder, Ohio Canner, Asgrow Canner, and Detroit Dark Red. All of these varieties grew well, and quality of edible roots was good. All reached edible size within 55 days from time of planting. Asgrow Wonder and Detroit Dark Red produced the largest tops—a desirable characteristic, particularly for home gardens. The Green Top Bunching has smooth, uniform, roots and glossy, attractive, but relatively small tops. The rapid growth and high quality of the crop also demonstrated the value of furrow irrigation and fertilizer placement. *(Frazier, Sumida, Tachibana)*

HEAD CABBAGE

A planting of 25 strains and varieties of head cabbage at Poamoho in mid-November 1941 was transplanted December 13, and harvested during the first 3 weeks of February 1942. Eight strains of Golden Acre, 8 of Copenhagen Market, and 3 of Marion Market were included in the trial. Considerable variation in earliness and in size and shape of head was noted among strains, depending upon seed source. Both Golden Acre and Copenhagen Market performed well at Poamoho during midwinter.

Repeated plantings of head cabbage were made during the summer of 1942 in the demonstration home garden on the University of Hawaii campus. Although all plantings have made heads, the heads have been small, and close attention to young plants has been necessary at all times for controlling the cabbage webworm. In addition to Golden Acre and Copenhagen Market, the varieties Early Baby Ballhead and Fordhook Forcing have been tried in the garden. These latter two varieties are early, small, dark-leaf types and are very similar in their plant characters. They should be satisfactory for small home gardens where they can be planted closely, and will produce the small heads desired by many gardeners. *(Frazier, Sumida, Tachibana)*

CARROTS

Imperator, Red Cored Chantenay, Improved Chantenay, and Danvers Half Long were planted in a variety test at Poamoho, November 6, 1941, with the planter described above. Imperator is an excellent long type of carrot that will give good results in deep, loose soils. All varieties produced smooth, moderately well colored roots. Temperatures at medium to low elevations, even in winter, are slightly too high for best color development. However, the carrot makes fairly satisfactory growth at all elevations throughout the year. *(Frazier, Sumida, Tachibana)*

CELERY

At low elevations the most successful celery crops have been secured by planting seed in early fall (September, October) for maturation during January to March. At high elevations successful crops have been obtained by growers during summer months. Plants grown during midsummer at low elevations, in experimental tests, have developed slowly, and have been small and of generally low quality.

The Special Utah (Utah Green) variety, a green-stalk type, has given consistently good results. Cornell No. 6 and Cornell No. 19, of the self-blanching type, have been given one trial in Hawaii, and appear superior to Golden Self-Blanching. *(Frazier, Tachibana, Sumida)*

BULB ONIONS

Several varieties of bulb onions (fig. 18) have been planted at Waipahu and Poamoho in fall and winter to determine behavior as influenced by planting date. A small planting was made at the Olinda substation on Maui on February 7, 1941, from seedlings grown at Waipahu. Transplants were also set out at Waipahu on this date so that a rough comparison could be made of the growth and maturation of the bulbs at the two locations. A general summary of the results of bulb-onion trials up to the present time follows:

1. Lower temperatures at Olinda delayed maturation of all varieties.
2. October and November plantings gave decided increases in yields over later plantings, made up to mid-February, on the Island of Oahu.
3. The Bermuda varieties (White, Yellow, Red) have given the most consistent high yields. Babosa (Grano) is relatively well adapted and has given excellent yields when planted early in the fall. It is slightly later than the Bermudas.

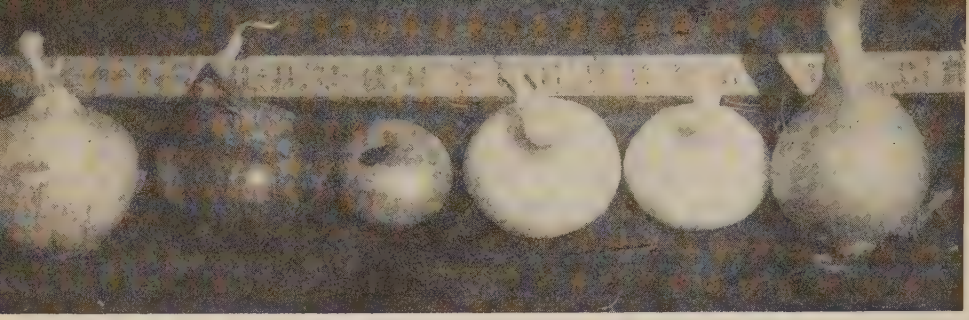


Figure 18.—Good yields of bulb onions have been obtained from seeds planted in the fall, with bulbs maturing in May and June at low elevations. Left to right, Babosa (Grano), Lord Howe Island (Red Bermuda), Red Creole, Yellow Bermuda, White Bermuda, and Sweet Spanish. Bulbs shown here were grown at Waipahu, Oahu, from seeds planted in November and harvested in June. The six onions pictured average about 1½ inches in diameter.

4. White Bermuda (Crystal Wax) has been the most susceptible of all varieties to doubling (splitting).
5. Doubling of all varieties tended to be severest in earlier plantings, and severer in nontransplanted than transplanted plants.
6. Red Creole, although a relatively low yielder, has been the only variety adapted to Hawaii's climate that keeps well at room temperatures in the Islands.
7. Heavy application of phosphate fertilizer was required in the Waipahu and Poamoho soils for good growth of bulb onions.
8. Onion seed has been successfully grown on the slopes of Haleakala by planting mother bulbs in the fall and harvesting the true seed in the spring. *(Frazier, Tachibana, Sumida)*

POTATOES

Varieties

Bliss Triumph remains the outstanding red-skinned variety for Hawaii. Pontiac, grown on Oahu in variety tests during 1940-41 and 1941-42, has given excellent yields, but its tubers have not had the bright red, blemish-free appearance of Bliss Triumph.

Among white varieties, Sequoia is the most promising new introduction. It was obtained for first trial in 1941-42, and must be given further testing.

Of the several hundred seedling introductions of white-skinned types brought to Hawaii 5 years ago, only five varieties remain. By continued selection (at Poamoho) for freedom from virus diseases, it has been possible to maintain stocks of these five accessions, which yield as well as Bliss Triumph. Seed stock has been sent to the United States Department of Agriculture to be tested for virus content during the past summer. If stock relatively free of virus disease is obtained from the Mainland, these accessions will be given further trial in Hawaii. *(Frazier, Sumida, Tachibana)*

Figure 19.—Size of seed piece has an important effect on yield under Hawaiian conditions. The three piles of potatoes on left (No. 1, No. 2, and culls) were produced on 25 feet of row, from 1-ounce seed pieces; those on right, from 25 feet of row, using 3-ounce seed pieces.

Seed Storage

It has been found that storage of tubers from the island-grown winter crop at a temperature of 38° F. permits the use of Bliss Triumph seed grown here. Total yields have compared rather favorably with yields from new mainland seed. Yield of No. 1 tubers has been relatively low from the island-grown seed, because of multiple sprouting and consequent increase in number of stems per hill and large numbers of rather small tubers.

Because of the cost of storage, lack of storage space, and ever-present danger of losses from rotting in storage, it is believed generally desirable to import certified seed stock for the major portion of the Hawaiian acreage. Under war economy it is clearly possible to store a portion of the winter crop for seed to be planted at high elevations in the summer or at low elevations in early fall. *(Frazier, Sumida, Tachibana)*

Seed Treatment and Seed Size

October plantings are normally seeded with potatoes that were dug only a few weeks previously in mainland fields. These potatoes may still be in a deep rest period, in which case they will remain dormant in the soil for many days, regardless of whether soil and climatic conditions are favorable for sprouting. Dipping *cut* potatoes in ethylene chlorohydrin, a method used in commercial plantings in Florida to break the rest period artificially, has also shown promising results under local conditions in irrigated fields.

Since cost of imported seeds is an important item in total production costs in Hawaii, growers have often raised the question whether seed pieces could be smaller than the usual 2-ounce size. Experiments (under irrigation) in 1940-41 and 1941-42 have shown that small seed pieces give lower yields. Table 26 shows the effect of seed-piece size and ethylene-chlorohydrin treatment on yields. The size given in the first stub refers to the size of the actual seed piece at planting; that is, if a 2-ounce potato was cut in half, the size of the seed piece was 1 ounce. Seed pieces cut in half were cut from tip to base, so that apical eyes were present on both halves. The treatment rate

on October 15, when seeds were rather deep in rest, was 1 part of ethylene chlorohydrin to 30 parts of water; on November 26, when seed pieces had sprouts ¼ inch or more long, the rate was 1 to 60. *(Frazier, Sumida, Tachibana)*

Table 26.—Effect of ethylene-chlorohydrin treatment and seed-piece size on potato yields. (Poamoho, 1941-42)

Seed-piece size	Type of seed piece and treatment	Yields, per acre	
		Planted Oct. 15 Harvested Jan. 28	Planted Nov. 26 Harvested Feb. 24
Ounces		*100 pounds*	*100 pounds*
1	Cut in half, treated with chlorohydrin	147	105
1	Cut in half, untreated	117	104
1	Cut in half, treated, and closely spaced[1]	170	124
2	Cut in half, treated with chlorohydrin	171	125
2	Cut in half, not treated	148	123
2	Whole, untreated	147	123
3	Cut in half, treated with chlorohydrin	181	141
3	Cut in half, untreated	161	136
3	Whole, untreated	157	133
4	Whole, untreated	177	147

[1] Spaced 6 inches apart in the row, rather than the usual 12 inches. Total weight of seed per acre was thus similar to that used for 2-ounce seed planted 12 inches apart.

Diseases

Early blight. Spraying to control early blight, *(Alternaria solani)*, has been continued. During the 1940-41 season, an effort was made to learn more concerning the effect of copper sprays (Bordeaux, Yellow Cuprocide) on the growth of the potato plant. Samples from sprayed and unsprayed plots, adequately replicated, were harvested at 10-day intervals, starting at 50 days after planting. Data were gathered on fresh weight of tops, fresh weight of tubers, and number of tubers per plant, at each date of harvesting. The tubers were also classified according to size; and presence or absence of scab *(Actinomyces scabies)* on tubers of different sizes was noted.

Data secured in this work show that when the potato plant is sprayed with a copper fungicide, particularly Bordeaux, it produces more tubers than an unsprayed plant, but that the average size of the tubers is smaller. Thus, although good control of *A. solani* was obtained this year with Bordeaux (as also in past seasons) and with Yellow Cuprocide, yields were not necessarily higher than from unsprayed but otherwise comparable plants.

Scab was as severe on sprayed as on unsprayed plants. This finding is in conflict with results obtained by New York State investigators. *(Parris, Kikuta)*

Nematode infection. Potato plants grown in sterilized and in both wet and dry nematode-infested soil produced tubers more severely injured by the

nematode, *Heterodera marioni,* in wet than in dry soil. However, there was a greater reduction in yield in dry-infested soil than in wet-infested soil.

Some evidence was obtained to indicate that lenticels on tubers are larger in wet soil than in dry soil. Nematode infection was invariably associated with a lenticel, and it is suggested that lenticels for the most part are entrance points for larvae of *H. marioni. (Parris)*

TOMATOES

Variety Testing

The Bounty variety, made available by the North Dakota Agricultural Experiment Station, was first tested in Hawaii during the late spring of 1941. It was planted in the University vegetable plots, and proved so promising for fruit set during relatively warm weather that seed was saved and distributed in small quantities for further trial in the Territory. On the basis of further trial and observations made during the summer of 1942, Bounty appears to be the best of the large fruit types for planting at low elevations during warm months. Because fruits tend to be rough, selections for smooth fruits are being made.

The summer temperatures of low elevations promote rapid vegetative growth of the tomato plant, with a decided tendency for poor fruit set. It is believed that this tendency is partly counteracted in a variety with the pronounced self-topping character of Bounty.

Approximately 300 successful crosses, involving a wide variety of tomato types, have been made, and some of the hybrid material is now in the F_3 generation. Year-round moderate temperatures in Hawaii permit the growing of at least 3 generations of tomatoes per year. Emphasis in breeding and selection has been placed on (1) heavy fruit set, especially in summer; (2) resistance to spotted wilt and melonfly attack; and (3) desirable fruit size and shape.

Parent stock, used for hybridization, was obtained from sources throughout the world. Simple and complex hybrids involving the following tomato types have been made:

Bounty, for large fruits, good set, earliness, and self-topping character.

Gardner, for resistance to spotted wilt.

German Sugar, for resistance to spotted wilt.

Grothens Globe, a Break O'Day type, for large, well-shaped fruits.

Pan America, for large fruits, and resistance to fusarium wilt.

Pearson, a dark green vine, semi-self-topping type, for firm, thick-walled fruits.

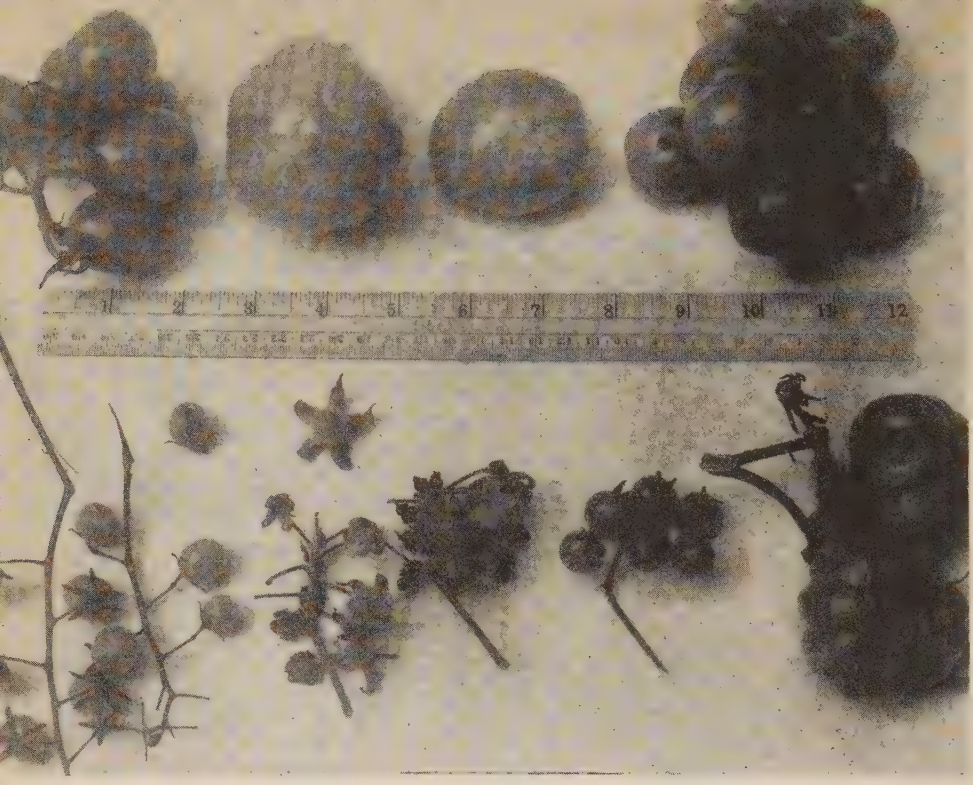


Figure 20.—Many tomato types are being used in the station's breeding program. Upper row, left to right: Common plum, Bounty, "Gardner," cluster of German Sugar. Lower row, left to right: *L. peruvianum, L. hirsutum,* Hawaiian Cherry, and Filipino.

Abundance, and other English Forcing types, for large clusters and rather good fruit set.

Italian (determinate) Plum, for the determinate vine characters, and extremely large clusters.

Hawaiian Cherry, a wild cherry tomato, widely scattered in the Islands, with very small fruit, for apparently considerable resistance to melonfly attack and for good fruit set in summer.

Summerset, a variety developed in Texas, for good fruit setting under high temperature conditions.

Filipino, an extremely rough fruit type, for better than average summer fruit set under our conditions.

Marglobe, Pritchard, and Valiant, commercial varieties, for good fruit type.

Lycopersicon hirsutum, for possible tolerance to common mosaic.

Repeated attempts to cross the common tomato with *L. peruvianum,* which is tolerant to nematode attack, have failed. *(Sumida, Kikuta, Frazier)*

Diseases

Spotted wilt. During the biennium, 54 varieties of tomatoes were tested for resistance to spotted wilt. A spotted-wilt-resistant tomato, introduced through the courtesy of Dr. M. W. Gardner of the California Agricultural Experiment Station, has received a number of trials locally. So far this BC-10 selection has remained immune to the virus disease while growing in areas where susceptible varieties suffered severely.

During 1941 the variety German Sugar was found to be highly resistant to spotted wilt. This variety was received from Dr. F. G. Krauss of Honolulu. Seeds of this and other varieties were given to members of the Experiment Station of the Hawaiian Sugar Planters' Association, who established resistance of German Sugar to spotted wilt by testing the seeds in a highly infested area at Kailua, Oahu.

Hybrids that have either of these two resistant selections as one of the parents are promising material for developing a resistant tomato plant with desirable fruit and plant characters.

Tomato accessions from Australia, previously reported (1940) to indicate resistance to spotted wilt, have not consistently remained free of disease.

Tomato mosaic. No promising mosaic-resistant varieties have been observed. Hybrids of *Lycopersicon hirsutum* × Marglobe, received from the United States Department of Agriculture, have not withstood the attack of this virus in Hawaii.

Fusarium wilt. Three lines of a third backcross to the hybrid Marglobe × *L. pimpinellifolium,* received from Dr. Wm. S. Porte, Washington, D. C., have been tested for the past year and a half, and claims for resistance to fusarium wilt have been substantiated. Grown in highly infested areas, these selections did very well, whereas other varieties succumbed to wilt. However, fruit setting was poor. *(Kikuta, Parris)*

ASPARAGUS

Eleven-month-old crowns of the Mary Washington variety were planted in the summer of 1939 at Poamoho to secure data on time of harvest, length of harvest, spacing, and sex. Results up to the present (after harvesting for 2 years) indicate that harvest periods of 5 weeks twice a year give the best results. Prolonging the harvest period has resulted in production of a relatively large number of small spears. Male or staminate crowns have produced a greater number of spears than female or pistillate crowns, although the latter produced larger spears. The yield of spears has tended to increase each year, although the experiment is still in early stages of development,

Figure 21.—Types of daikon (winter radish), left to right: Four early-maturing, short-rooted, Chinese types of daikon, two semi-long mainland varieties, and a long-rooted, slow-maturing Japanese daikon.

and data for 1 or 2 more years must be secured before definite conclusions can be drawn. *(Sumida)*

DAIKON

Daikon (winter radish) is widely used in the diet of the oriental population in Hawaii. Before the war much of the daikon seed came from the Orient. In a test devised to compare oriental with mainland daikon, it was found that certain mainland varieties—White Chinese, Celestial, Chinese White Wonder, and California Mammoth White—are fair substitutes for

local- or oriental-grown stocks. Mainland varieties were semi-long-rooted, or intermediate between the short-rooted, early-maturing Chinese daikon and the long-rooted, late-maturing Japanese type. *(Frazier, Sumida, Tachibana)*

YEAR-ROUND GARDEN

A 50-by-25-foot experimental home garden was begun in March 1942 at the University plots. Repeated plantings of a wide variety of crops permit the recording of year-round adaptability data, and complete yield records will demonstrate the potential annual food production from a plot of this size.

With proper cultural care and insect control, excellent crops of greens can be grown the year around in Hawaii. The luxuriant growth shown in the frontispiece was obtained in mid-July in the experimental home garden. *(Tachibana, Frazier)*

DAMPING-OFF STUDIES

Studies to determine the most effective controls for pre-emergence damping-off of seedlings have been completed and results published. The two chemicals found to give effective control were Semesan and cuprous oxide (red copper oxide); recommendations for specific crops are given below:

Red copper oxide only: on celery, lettuce, and tomato.

Red copper oxide slightly better than Semesan: on eggplant.

Semesan better than red copper oxide: on cabbage, cauliflower, cucumber, kale, okra, peas, pumpkin, radish, spinach, and turnip.

Semesan slightly better than red copper oxide: on alfalfa, string bean, kohlrabi, squash, and Swiss chard.

Semesan or red copper oxide: on beet, carrot, melon, and pepper. *(Matsuura)*

ENTOMOLOGICAL PROBLEMS

The present entomology division of the station had been in existence only 4 years when war struck Hawaii. During the first 3 of these, the primary project was to survey major insects of local crops, and to do some exploratory work on problems brought into special prominence by these investigations.

Increasing tension in international affairs stressed the need for concentrating on the insect problems of those crops that would be of greatest food value should shipping to Hawaii be curtailed. As a result of this focus of

attention, the station was in a position, when the test came, to make recommendations for the control of most of the major insects of the important crops.

Some of the insects which attack food crops in Hawaii are now cosmopolitan; others are indigenous; some have come from the Orient, some from Southern Europe, some from North America, and some from South America. Against certain of these insects no investigational work had been undertaken either in Hawaii or elsewhere. On none of the crops in Hawaii is present the particular combination of insects and diseases found in any other place. The problem of controlling the insects of Hawaiian food crops has thus called for initial investigational work on some insects, for the recognition of particular sets of problems on each crop, and for appreciation of the conditions of climate and production characteristic of Hawaii.

During the biennium particular attention has been given to the insect problems of sweetpotato, bean, tomato, cabbage, and potato. Investigations have been undertaken also on the control of beet webworm on beet, corn earworm on sweet corn, and on insects of several other miscellaneous vegetables. Several problems not previously met have arisen: Greenhouse white fly has become a serious pest of green beans in the hot dry sections; a tiny capsid bug has destroyed seedlings of beet, carrot, chard, and cabbage; and an eriophyid mite has caused severe injury to tomatoes. In the fall of 1940, losses of young calves occurred during the first 2 weeks of life through the attack of blowflies.

Excellent cooperation has been secured from plantations and individual growers, who readily made available crops for many of the experimental studies on insect control.

By the development of control measures for our major insects, and by the elucidation of new or obscure insect problems, vegetable production in Hawaii is being placed on a sounder basis than it has ever been before. In the past, losses from insect depredations have been one of the most serious aspects of vegetable production; insect control measures have been limited, haphazard, and largely unreliable. Now, as a result of station research, it is possible to make trustworthy recommendations with confidence. These recommendations are being followed throughout the Territory.

INSECTS OF SWEETPOTATO

The major insects of sweetpotato are: Sweetpotato leaf miner *(Bedellia orchilella),* sweetpotato stemborer *(Omphisa anastomosalis),* sweetpotato weevil *(Cylas formicarius),* and West Indian sweetpotato weevil *(Eusepes postfasciatus).* The leaf miner can cause defoliation. Severe attacks reduce

the yield and may cause the death of plants that are not well established. The stemborer larvae bore in the vines and in the main stem, and may penetrate to the roots and tunnel in them. The weevils cause severe injury to the tubers but may breed also in the stems.

Control of Sweetpotato Leaf Miner

In a preliminary study on control of leaf miner, comprising 12 treatments, highest mortality was secured with a 1:4 rotenone-sulfur dust (1 percent rotenone) and a spray of nicotine plus white-oil emulsion (1:600 nicotine sulfate and 1¼ percent oil emulsion). Three weeks after treatment the plots treated with nicotine plus white-oil emulsion showed least attack.

In a second study, following up these results, the treatments (14 in number) comprised various rotenone mixtures as dusts and as sprays, and oil-emulsion sprays with both nicotine and rotenone. The leaf-miner infestation was not far advanced, and most of the larvae were comparatively young when the study was made. Control of exposed larvae, and of unexposed and partially exposed larvae, was again greatest with the nicotine sulfate plus white-oil emulsion (100-percent control of exposed larvae and 55-percent control of unexposed or partially exposed larvae). Control of exposed larvae was 100 percent also with rotenone-sulfur dust, a spray of rotenone plus fish-oil soap (4 lb. rotenone plus 1 pt. fish-oil soap per 100 gal.), a spray of rotenone plus diesel-oil bentonite emulsion[6] (4 lb. rotenone plus 10 pt. diesel-oil bentonite emulsion per 100 gal.), a commercial rotenone spray (Berako) and a white-oil emulsion spray (10 pt. per 100 gal.). Effectiveness of materials against unexposed and partially exposed larvae was second and third respectively with sprays of rotenone plus white-oil emulsion (2 lb. rotenone plus 10 pt. white oil per 100 gal.) and rotenone plus wettable sulfur (4 lb. rotenone plus 5 lb. wettable sulfur per 100 gal.).

In a third experiment, including seven treatments, nicotine sulfate with white-oil emulsion, which had given such good results in the previous experiment, was compared with nicotine sulfate plus the much cheaper diesel-oil bentonite emulsion; the best rotenone treatments to date and cryolite dust (50 percent) were included. Nicotine with diesel-oil bentonite emulsion gave superior control of exposed larvae to that secured from nicotine plus white-oil emulsion. The kill of unexposed and partially exposed larvae was comparable in both treatments, although apparently slightly higher with the white oil.

---

[6] Diesel-oil bentonite emulsion or "pineapple oil" is the emulsion developed by Dr. Walter Carter for the control of pineapple mealy bug (CARTER, W. DIESEL OIL EMULSIONS AS INSECTICIDES. Jour. Econ. Ent. 28(2): 268-284). It is now manufactured locally and is available commercially, ready for use.

Cryolite dust gave maximum kill of exposed larvae but minimum kill of unexposed and partially exposed larvae. Rotenone plus diesel-oil bentonite emulsion gave excellent all-around control. The superiority of oil-emulsion treatments over others is apparently due in part to ovicidal action of the emulsion. From the work to date, sprays of nicotine plus diesel-oil emulsion and rotenone plus diesel-oil emulsion are outstanding for control of sweetpotato leaf miner. In view of the wartime shortage of rotenone and its superior value for use on vegetable greens, it is not recommended for general use on sweetpotato, particularly when another satisfactory method of control, the nicotine plus diesel-oil-emulsion treatment, is available. This latter method has been used successfully in practice, with resulting increased yields. *(Holdaway, Look, Lucas, Nishida)*

Protection of Sweetpotato Cuttings Against Stemborer

A search has been made for a satisfactory material into which to dip sweetpotato cuttings, before planting, to control the stemborer. The study has indicated that cryolite, acid arsenate of lead, Paris Green, and calcium arsenate are promising. *(Holdaway, Look, Nishida)*

Control of Sweetpotato Weevils

Cryolite has been shown to control West Indian sweetpotato weevil, the more important of the two species of weevil attacking sweetpotatoes in Hawaii, but comprehensive comparative studies of insecticides have not yet been made, although it is known that arsenate of lead will also control the weevils. *(Holdaway, Look)*

INSECTS OF BEANS

The major insects of beans are Chinese rose beetle *(Adoretus sinicus)*, bean leafhopper *(Empoasca solana)*, bean-pod borer *(Maruca testulalis)*, the bean capsid *(Pycnoderes quadrimaculatus)*, the cowpea aphid *(Aphis medicaginis)*, and two mites *(Hemitarsonemus latus* and a species of *Tetranychus)*. Lima beans are, in general, not severely attacked by rose beetle, but are more susceptible to pod borer than are green beans. Chinese rose beetle is a foliage consumer; the pod borer destroys blossoms, pods, and stems; the other insects are sap suckers. The aphid may be readily controlled with nicotine sulfate, the mites with sulfur. Research was necessary on control of the other insects.

Control of Chinese Rose Beetle

Cage studies to date on 20 materials have revealed only one—acid arsenate of lead—that is highly toxic to the rose beetle. This material can be

used to control rose beetle on crops such as eggplant and litchi, which are not adversely affected by it, and on many ornamentals, but it commonly causes injury to the foliage of green beans. Studies are therefore in progress to find a satisfactory corrective for use with arsenate of lead on beans, while the search for other materials toxic to rose beetles is being continued. *(Holdaway, Nishida, Tanada*[7]*)*

Control of Bean Leafhopper

In a study of 10 materials to destroy bean leafhopper on green beans, almost complete control (93 to 95 percent) was secured with a pyrethrum-sulfur dust (1:9 yielding 0.2 percent pyrethrins), a spray of pyrethrum plus wettable sulfur (4 lb. of 2-percent pyrethrum and 5 lb. wettable sulfur per 100 gal.), and a pyrethrum-talc dust (0.2 percent pyrethrins). Residual value of the treatments, as indicated by the population 6 days after treatment, was greatest in the plots treated with the pyrethrum-sulfur dust.

Less satisfactory but promising initial control was secured with sulfur dust, wettable-sulfur spray (5 lb. per 100 gal.), and talc dust. Residual effect was not high with Bordeaux. It appears that this lack of response to Bordeaux may be associated with the fact that the crop was practically mature, with growth almost at a standstill.

In a further study, on the highly susceptible blackeye cowpea, in a young, actively growing stage, 16 treatments, including copper compounds (Bordeaux and copper oxide), pyrethrum, and sulfur, were compared. The leafhopper population was comparatively high at the time of the first applications. Second applications were made 7 days after the first.

Initial kill was highest with a commercial pyrethrum-rotenone spray (Foliafume, 1:500), but the leafhopper population built up again rapidly. A spray of copper oxide plus pyrethrum (1½ lb. yellow cuprocide plus 4 lb. of 2-percent pyrethrum powder per 100 gal.) and sprays of wettable sulfur plus pyrethrum (5 to 10 lb. wettable sulfur plus 4 lb. of 2-percent pyrethrum powder per 100 gal.) were also very effective in immediate kill. Residual effect, as measured by the population 12 days after the first application, was greatest and hence plant protection at a maximum with a Bordeaux spray. The formula was a low copper mixture (3-5-50) made with hydrated lime. Yields were highest, in order, from sprays of Bordeaux plus nicotine sulfate (1:600), pyrethrum plus wettable sulfur (4 lb. of 2-percent pyrethrum plus 10 lb. wettable sulfur per 100 gal.), and Bordeaux alone.

Protection was promising, with 38-percent survival, in the plots sprayed with copper oxide (yellow cuprocide). Some protection was secured with all the sulfur treatments.

[7] Temporary employee.

Good practical control and excellent production of the black-eyed cowpea have been secured from a single spraying with Bordeaux *when the leafhopper population was low* and the plants were actively growing. For a mixed infestation of bean leafhopper and bean capsid on Bountiful and Stringless Green Pod bush beans, Bordeaux plus wettable sulfur (5 lb. per 100 gal.) proved to be practical. *(Holdaway, Look, Lucas)*

Control of Bean Capsid

Such data as have been secured on the control of bean capsid on bush beans suggest promising results from a pyrethrum-sulfur dust (1:9 yielding 0.2 percent pyrethrins), a pyrethrum-talc dust (1:9 yielding 0.2 percent pyrethrins), a lime dust, and a talc dust. Limited observations on the effectiveness of the pyrethrum-sulfur dust in comparison with rotenone-sulfur dust (1:4 yielding 1 percent rotenone) and a pyrethrum-lethane dust (L-Py, 0.1 percent pyrethrins, 1 percent lethane) indicated that the rotenone dust, and to a lesser extent the lethane-pyrethrum mixture, were superior to the pyrethrum-sulfur dust. Promising results have been suggested with a rotenone-sulfur dust (0.75 percent rotenone), a rotenone-talc dust (0.75 percent rotenone), and a lime-nicotine dust (3 percent nicotine). Practical operations indicate good control with the lime-nicotine dust and a spray of nicotine sulfate plus fish-oil soap (1:600 nicotine sulfate plus 1 pt. per 100 gal. fish-oil soap). *(Holdaway, Look, Nishida)*

Control of Bean-Pod Borer

Good control of bean-pod borer had been reported with a spray of tetramethyl thiuram disulfide, applied at a strength of 2½ pounds per 100 gallons (Annual Report, 1940). The material apparently acts mainly as a repellent. The cost is comparatively high.

In a search for other effective insecticides, a comparative study of cryolite, rotenone, and calcium arsenate has been made on a pole variety of lima bean, King of the Garden. The materials were applied as dusts, the cryolite and calcium arsenate at a strength of 60 percent and the rotenone in a mixture containing 1 percent rotenone. A synthetic cryolite containing 83 percent sodium fluoaluminate was diluted with talc and again with sulfur. Calcium arsenate was applied with hydrated lime and with sulfur as diluents. The rotenone dust was a 1:4 rotenone-sulfur mixture. Two applications were made at an interval of 10 days. After the second application, when there were heavy dews and some rain, considerable plant injury occurred in the plots treated with calcium arsenate. Injury was particularly marked with the mixture diluted with lime.

A comparison of treatments was made on the basis of the first six harvests, which included the peak of the harvest.

Cryolite gave an average increase of 39 percent in total yield and an average increase of 55 percent in the yield of sound pods. The increase with the cryolite-talc mixture was 56 percent on the basis of total yield and 74 percent on the basis of sound pods. The rotenone-sulfur mixture gave no control and a decrease in yield. Calcium arsenate, while giving some control, was detrimental because of foliage injury. The foliage of plants in the cryolite-treated plots was darker green than the foliage in the other plots.

Good practical control of pod borer has been secured with cryolite applied as a spray at strengths from 4 to 6 pounds per 100 gallons. The first application of insecticide should be made at the onset of flowering. *(Holdaway, Look)*

INSECTS OF TOMATO

The most widespread insect of tomatoes in Hawaii is the corn earworm or tomato fruitworm *(Heliothis armigera)*. It is always a potential menace to the crop and at times may be devastating in its attack.

Control of Corn Earworm

Work to date has consisted of an experimental study of a cryolite spray and a cryolite-cornmeal bait. The spray was applied at a strength of 6 pounds per 100 gallons. Copper oxide (yellow cuprocide) was included at the rate of 1½ pounds per 100 gallons, and neutral fish-oil soap (Nopco) was added at the rate of 1 quart per 100 gallons as spreader sticker. The bait consisted of 1 pound of cryolite to 10 pounds of corn meal, mixed and applied dry.

Three applications of the spray gave an increase in yield of over 45 percent, and five applications of the bait gave an increase in yield of over 56 percent. These yields represented advances of from 3 to 3.8 tons per acre. The increases were obtained even though the field, including the plants used in the check plots, had had two applications of insecticide before the crop was made available for experimental purposes. The increase in yield due to the insecticides must undoubtedly have been greater than that indicated by the foregoing figures. Moreover, since the crop suffered somewhat from lack of water, the increase in yield would no doubt have been greater if the plants had experienced satisfactory growing conditions.

At low elevations, where rainfall is low and night showers are infrequent, cryolite can be satisfactorily applied as a dust or as a spray. The spray, to which can be added nicotine sulfate for the control of aphids when necessary, and copper oxide as a fungicide, has been widely adopted for the control of corn earworm on tomatoes in Hawaii. The cryolite, applied primarily for the control of corn earworm, automatically takes care of several

other insects should they appear—flea beetle *(Epitrix parvula),* beet armyworm *(Laphygma exigua),* nutgrass armyworm *(Laphygma exempta),* green garden looper *(Autographa chalcites),* and tomato pinworm *(Gnorimoschema lycopersicella). (Holdaway, Look)*

INSECTS OF CABBAGE

The most widespread of the major insects of head cabbage and related plants are cabbage worm or cabbage butterfly *(Pieris rapae),* cabbage webworm *(Hellula undalis),* cutworms, and aphids. Of these insects the most devastating, because of the insidious nature of its attacks, is the cabbage webworm. At low elevations, from sea level to 700 feet, cabbage webworm is present throughout the year and is one of the most important factors affecting cabbage production, especially during the warm months when it is most abundant. Seedlings may be attacked as early as the second-true-leaf stage; the growing point is eaten out and the potential head ruined.

In normal times most of the head cabbage grown in Hawaii, particularly during the warm months, is produced on the Islands of Maui and Hawaii, at elevations from 1,000 to 4,000 feet, where cabbage webworm is seldom a problem.

As the emergency developed, it became apparent that any situation which led to a curtailment of inter-island shipping would transfer to the Island of Oahu the responsibility for producing many vegetables that were in normal times grown on the other islands. In particular would Oahu have to produce head cabbage and the many related plants such as Chinese cabbage, broccoli, spoon cabbage, and mustard green. Since all the arable land on Oahu is situated at elevations below 1,000 feet—most of it below 800 feet—cabbage webworm loomed as potentially the most serious insect of cabbage and related plants. With the declaration of war and the cessation of inter-island vegetable shipments, the potential seriousness of cabbage webworm was thrown into bold relief.

Control of Cabbage Webworm

Studies have been made to determine a satisfactory method of controlling cabbage webworm. Because of the waxy surface of cabbage leaves, dusts are usually superior to sprays for control of cabbage insects. However, since the field equipment for insecticides available in Hawaii is predominantly for sprays, it was deemed advisable to seek a spray which would give satisfactory control. Of eight materials studied for wetting power of cabbage leaves, Vatsol OT was best and sulfonated castor oil next. In view of the high sticking properties of sulfonated castor oil, it has been used as wetter

Figure 22.—Part of an extensive range of cruciferous crops—Chinese cabbage, mustards and other greens, and daikons—grown successfully by the truck crops department of this station during midsummer at the University of Hawaii campus under conditions conducive to severe webworm injury. Cabbage webworm was successfully controlled by dusting with a cryolite-talc dust (50 percent cryolite) twice at an interval of 10 days. On the left, spoon cabbage (Shakushina); on the right, Pak Choy, a closely related plant. Both are commonly referred to as white mustards.

sticker in the spray treatments. Vatsol OT (1:4000) was also used, for comparison, in one of the cryolite treatments. The materials studied as dusts and sprays were cryolite, calcium arsenate, Paris Green, barium fluosilicate, and rotenone. Paris Green was applied at the rate of 2 pounds per 100 gallons and the other sprays at concentrations of 4 pounds per 100 gallons. Sulfonated castor oil was used at a dilution of 1:200, or 2 quarts per 100 gallons.

Calcium-arsenate dust was applied straight, cryolite dust as a cryolite-talc 1:2 mixture, rotenone as rotenone-talc 1:4 (1 percent rotenone), and Paris Green with lime as a 1:9 dust. The study involved 800 plants of Copenhagen Market.

The first application of insecticides was made while the seedlings were in the seed flats. Transplanting followed soon after. Applications were made at intervals of 10 to 12 days. Records of insect infestation were made just prior to each successive application.

Rotenone dust and cryolite dust consistently gave better protection than any of the other treatments, with Paris Green spray somewhat less effective. In view of the fact that cryolite is cheaper than rotenone and more readily obtainable at the present time, it has been recommended for field control of

cabbage webworm. The cryolite-dust treatment is meeting with marked practical success. Chinese cabbage and many other leafy and root crucifers susceptible to cabbage webworm have been grown successfully in the middle of summer at low elevations—conditions conducive to the most severe attacks from cabbage webworm—with only two applications of cryolite dust.

Although information secured in the first exploratory study was insufficient for general recommendations regarding a *spray* for control of cabbage webworm, information secured in the course of an experiment on the control of cabbage worm, reported below, indicates promising results from sprays of somewhat higher strengths than those used in the first study—cryolite, at a strength of 6 pounds per 100 gallons, plus sulfonated castor oil, and acid arsenate of lead plus astringent, at a strength of 6 pounds per 100 gallons, plus sulfonated castor oil. *(Holdaway, Look, Nishida, Tanada*[8]*)*

Control of Cabbage Worm (Cabbage Butterfly)

In the experiment on control of cabbage webworm, records were made also of infestation by cabbage worm *(Pieris rapae)*. At the first record, 11 days after application, rotenone dust gave the greatest protection, 17 larvae per 100 plants, against 48 per 100 plants in the check plots. Rotenone spray and Paris Green spray were next in effectiveness. Rotenone spray and dust were consistently high in protection as later records were taken.

Control of cabbage worm has been studied further in an experiment carried out in January 1941 at Poamoho Experimental Farm, when cabbage worm was the most important insect. The study included 12 treatments—2 rotenone dusts, 2 rotenone sprays, Paris Green spray, Paris Green dust, 2 cryolite sprays, and 4 arsenate of lead sprays. The experiment was designed to determine effectiveness of the respective treatments in terms of kill and retention; records were taken 2 days, 10 days, and 16 days after treatment.

Initial toxicity, as measured by infestation counts 2 days after treatment, was highest with rotenone-bentonite dust (1 percent), which gave complete protection. High initial protection (from 84 to 78 percent) was also secured, in order, from Paris Green spray (3 lb. per 100 gal.), rotenone-talc dust, and rotenone spray. Effectiveness at the end of 16 days, involving retention of the insecticide, was highest (90 percent) with standard arsenate of lead (5 lb. per 100 gal). A spray of rotenone plus sulfonated castor oil (4 lb. of 5-percent powder per 100 gal. plus ½ gal. sulfonated castor oil) gave 78-percent control. Plants treated with sprays containing sulfonated castor oil exhibited injury on those leaves which retained the spray in cuplike depressions. *(Holdaway, Look, Nishida)*

[8] Temporary employee.

INSECTS OF MISCELLANEOUS CROPS

Control of Insects on Beets and Chard

Beet webworm, *Hymenia recurvalis (fascialis),* known in mainland literature as "Hawaiian beet webworm," is one of the two most important insects of beet and Swiss chard. Attack by beet webworm is likely to occur at any time of the year at low elevations but is usually most devastating in the spring and early summer. Even when foliage of mature beets is attacked, the commercial value of the crop is considerably reduced. The other "insect" is the tiny "broad mite," *Hemitarsonemus latus.* Investigations by workers elsewhere have indicated the superiority of pyrethrum over other insecticides for control of beet webworm; arsenicals and rotenone have been considered unsatisfactory by these workers. Experiments have been conducted to determine the most effective way of applying pyrethrum and to study the effectiveness of various pyrethrum products available locally.

In the first study the six treatments tested were pyrethrum (Impregno)-talc dust 1:9, pyrethrum (Impregno)-sulfur dust 1:9, pyrethrum (Dry Pyrocide)-talc dust 1:9, a commercially prepared dust (Botano Py 20), pyrethrum (Impregno)-Vatsol O.S. spray (4 lb. per 100 gal.), and pyrethrum (Imazu)-Vatsol spray (4 lb. per 100 gal.). All the dusts contained 0.2 percent pyrethrins, and the Impregno spray, 0.009 percent pyrethrins. The concentration in the Imazu spray was unknown.

Two applications were made at an interval of 14 days. Infestation counts made after the first application indicated 100-percent control with the commercial dust (Botano Py 20) and good control with the pyrethrum sprays. The infestation, however, was still comparatively low and the relative effectiveness of the respective treatments was inconclusive. Records made after the second application, by which time the infestation had increased, indicated the superiority of the dusts over the sprays. Again 100-percent control was obtained with the commercial dust (Botano Py 20) and good control with all three other dusts (30, 35, and 39 larvae per 100 leaves against 67.5 and 88 larvae with the pyrethrum sprays and 210 in the untreated checks.) Plants in the plots treated with pyrethrum-sulfur dust were dark green and lush in growth whereas the plants in the other plots exhibited red leaves and were less vigorous.

In a second study, nine treatments were compared comprising four pyrethrum dusts, two sulfur dusts, a spray of pyrethrum plus wettable sulfur, wettable-sulfur spray, and a commercial pyrethrum-rotenone spray (Foliafume). Two applications were made at an interval of 9 days.

Results after the first application again showed the pyrethrum dust (Botano Py 20) to be superior, 2 living larvae per 100 leaves, against 726 in the check or over 99-percent control. The next most effective treatment was the pyrethrum-sulfur dust, with 75 larvae per 100 leaves or a control of approximately 90 percent.

After the second application, pyrethrum dust (Botano Py 20) and the pyrethrum-sulfur dust were superior (3 and 10 living larvae per 100 leaves, respectively, against 400 in the check plots, representing 99-percent and 97.5-percent control). The effectiveness of the other treatments followed in this order: Pyrethrum-sulfur-bentonite dust, a spray of pyrethrum plus wettable sulfur, pyrethrum-talc dust, and sulfur-bentonite dust (from 95- to 90-percent control). The commercial pyrethrum-rotenone spray (Foliafume) gave 85-percent control and sulfur dust alone, 77-percent control.

The reason for the superiority of the foliage in plots treated with pyrethrum-sulfur dust in the preceding experiment was not at first appreciated. It can now be stated quite definitely, however, that one reason, and probably the main reason, for the superiority of the treatments containing sulfur dust lay in the fact that the mite *Hemitarsonemus latus* had been controlled by the sulfur.

The bean leafhopper *(Empoasca solana)* is an occasional pest of beets (and chard). Records were made of the leafhopper infestation in the various plots during both experiments on control of beet webworm. In the first experiment the two outstanding treatments were pyrethrum-talc dust and pyrethrum-sulfur dust. In the second experiment, control was highest with pyrethrum-talc dust and the commercial pyrethrum dust (Botano Py 20). These results, as far as they go, are in line with those secured in other experiments concerned specifically with control of bean leafhopper, but made on beans.

In view of the fact that a pyrethrum-sulfur dust has been shown to control the three main insect pests of beet and chard—beet webworm, broad mite, and bean leafhopper—it is recommended as an all-purpose treatment for insects of beet and chard in Hawaii. *(Holdaway, Look)*

Control of Corn Earworm in Sweet Corn

Since the introduction into Hawaii, by this station, of the variety U.S.D.A.-34, sweet-corn production has increased markedly. Although the husk of this variety is tight, and the extent of injury to individual ears by corn earworm *(Heliothis armigera)* is consequently less severe than in varieties with looser husks, it is not uncommon to find 100 percent of the ears attacked by earworm.

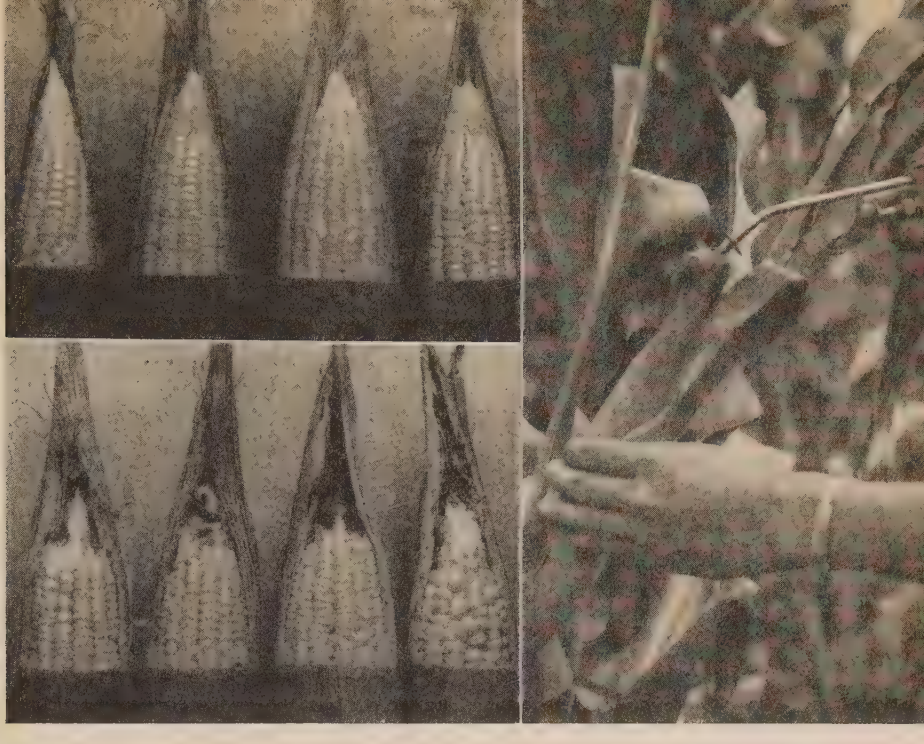


Figure 23.—Mineral-oil treatment protects sweet corn from attack by earworm. Upper left: Ears of sweet corn (variety U.S.D.A.—34) that have been treated with mineral oil. Lower left: Untreated ears, attacked by earworm. Right: Applying mineral oil to the tips of sweet corn.

For many years, methods of control of earworm in sweet corn have been far from satisfactory. Recently a promising method has been developed by G. W. Barber[9] of the United States Bureau of Entomology. This method is the mineral-oil treatment. As used on the Mainland, the method consists of injecting from ¾ to 1 cubic centimeter of refined mineral oil—commonly with pyrethrum extract or dichloroethyl ether added to increase the efficiency of the oil—into the end of the ear after fertilization (i.e., after the silks have shrivelled). Nissley[10] has recommended the use of lubricating oil. Bailey[11] in Puerto Rico and Schmidt[12] in Hawaii have added rotenone to the refined oil.

The mineral-oil treatment has been studied to determine its value under Hawaiian conditions. In the first experiment, individual treatments included refined oil alone; refined oil combined with each of the following materials:

---

[9] Barber, G. W. mineral oil treatment of sweet corn for earworm control. U. S. Dept. Agr. Cir. 657; 15 pp. 1942.

[10] Nissley, C. H. worm-free sweet corn. Country Gentleman 110(10): 74. 1940.

[11] Bailey, W. K. experiments in controlling corn ear pests in puerto rico. Puerto Rico Exp. Sta. Cir. 23; 23 pp. 1940.

[12] Schmidt, C. T. earworm control in sweet corn. Hawaii Ent. Soc. Proc. 11(2): 195-197. 1942.

0.2 percent pyrethrins, 0.075 percent rotenone, 1 percent dichloroethyl ether, and 2 percent dichloroethyl ether; and lubricating oil with 1 percent dichloroethyl ether. The refined oil was a medicinal oil, "Hydrol," with viscosity 185-195 Saybolt seconds. The lubricating oil was one in common use for lubricating automobile engines, R.P.M. SAE 30, with a viscosity of 560 seconds. A pistol oiler, calibrated to eject 0.8 cubic centimeter of oil per squeeze of the trigger, was used to apply the oil. The first study involved 520 ears of U.S.D.A.-34.

Although lubricating oil gave excellent control with only 1 percent dichloroethyl ether, it tended to cause discoloration of the ear and to impart an odor of oil to the ear. Lighter oils would penetrate farther onto the ear and thus be expected to be even less satisfactory than the comparatively heavy oil used. The strength of pyrethrum studied, although recommended for mainland conditions, was unsatisfactory because it caused considerable silk rotting, with associated pungent odor. Inclusion of rotenone and of 1 percent dichloroethyl contributed little or no improvement to the control. Inclusion of 2 percent dichloroethyl ether, while improving the control, caused considerable silk rotting. The appearance of the ears suggested that satisfactory control might be secured with less than 0.8 cubic centimeter of oil.

Refined mineral oil alone (0.8 cubic centimeter per ear) gave almost as great a number of worm-free ears as did the treatments containing insecticides, and without the deleterious effects. The control with mineral oil alone (78 percent of the ears exhibiting no larval injury and 90 percent exhibiting no or negligible injury) was comparable to that secured by Barber on the Mainland with oil containing 0.2 percent pyrethrins or 2 percent dichloroethyl ether.

In a second experiment refined mineral oil alone was again studied at the rate of 0.8 cubic centimeter per ear and in smaller quantities (0.6 and 0.4 cubic centimeter per ear). Concentrations of pyrethrins and dichloroethyl ether were reduced to 0.075 percent and 1.5 percent, respectively. Rotenone (0.075 percent) was studied again, this time with the three different quantities of oil. In addition, the effect of placing the oil on the silk as near to the tip of the ear as possible, as was done by Schmidt, was compared with the method used in the previous experiment, of applying the oil inside the end of the ear to the silk channel. The number of ears studied was 418.

Results of the second experiment indicated that addition of chemicals, at the strengths used, did little to improve the effectiveness of the treatment. Moreover, even at these lower concentrations there was evidence of silk

injury and rotting. Control with 0.8 cubic centimeter of oil was superior to that with 0.6 cubic centimeter; 0.4 cubic centimeter was definitely too low.

In a third experiment, oils with three different viscosities were studied: "Hydrol" with viscosity 185-195 seconds at 100° F. (used in the first two experiments), Oronite Crystal Oil No. 7 with viscosity 145-155 seconds, and Oronite Crystal Oil No. 5 with viscosity 100-110 seconds. Concentrations of pyrethrins (0.075 percent, 0.05 percent and 0.025 percent) and dinitro-orthohexylphenol (1 oz. per gal.) were also studied with each oil. The number of ears was 826.

The infestation in this experiment was lower than in either of the other experiments. The results showed only slight differences in effectiveness of the three oils studied. Addition of pyrethrum increased the effectiveness of the treatments slightly but also gave an increase in the percentage of ears affected with odor. Addition of dinitro-orthohexylphenol, while increasing the protection from earworm, was unsatisfactory because of severe injury to the ears.

From the point of view of effectiveness in preventing injury and minimum odor imparted to the treated ears, the lightest oil studied, the Oronite Crystal Oil No. 5, was slightly superior to the others.

The general conclusion reached from the experiments to date is that under Hawaiian conditions, and with the tight husked U.S.D.A.-34, insecticides added to the mineral oil contribute so little increased efficiency and moreover impart such adverse characteristics to the treated ears that they cannot be recommended. Straight refined mineral oil of viscosity 100-200 seconds, at the rate of 0.8 cubic centimeter per ear, gives excellent protection (75 to 84 percent ears with no injury and 79 to 91 percent of ears with no or negligible injury). *(Holdaway, Look, Nishida)*

MISCELLANEOUS INSECT PROBLEMS

Several insects not heretofore prominent have become important during the biennium and have received the attention of the entomology division, and the effect of other insects previously not fully understood has been elucidated.

Greenhouse White Fly a Pest of Green Beans

During the early months of 1941, white flies became very abundant on green beans in the Waianae section of the Island of Oahu. At a similar season the previous year they had been present on beans, but not in such serious abundance. The Territory is normally self-sufficient with respect to

green beans; Oahu is the largest producer of the Islands, and approximately 40 percent of the crop grown on Oahu comes from the Waianae section. The pole variety Lualualei, grown almost exclusively in this section, normally yields from 10 to 14 harvests per crop. At the peak of the white-fly infestation, harvests were reduced to one or two, and in some plantings were prevented completely.

The fly has been identified as greenhouse white fly, *Trialeurodes vaporariorum,* a species which has been present in Hawaii for many years but which has not formerly been a serious pest of any crop.

Chemical control of the white fly has not, to date, been very successful, and such measures as have been used have been expensive. The entomologist of the Board of Agriculture and Forestry has therefore been requested to introduce into Hawaii the parasite *Encarsia formosa,* which successfully controls greenhouse white fly in England, the United States, and Canada. *(Holdaway)*

Mirid Bug Found to Attack Beets and Carrot Seedlings

During early summer of 1942, reports were received of losses of beet plantings. Injury, which was apparent in the young seedlings in the cotyledon stage, was thought variously to be fertilizer burn, "damping-off," or cutworm injury. Investigation demonstrated that the cause of the injury was a tiny mirid bug, *Leucopoecila albo-fasciata.* Injury, first evident as a shrivelling of the cotyledons, was found to be quite marked 8 hours after bugs were confined over seedlings. Carrot, chard, and cabbage seedlings are also affected. Pigeonpea seedlings have been attacked, but less devastatingly. Beets and carrots appear to be the most severely affected. To date the chemical control measures studied have not been promising. Mechanical protection of seedlings by means of light cloth until the first true leaves appear will permit production of a crop. To date the injury has been observed only in early summer. *(Holdaway, Look, Nishida)*

Broad Mite (Hemitarsonemus latus)

A tiny white mite *(H. latus)* known in mainland United States as the "broad mite," (and a comparatively common pest of greenhouse plants) has been found to be a serious pest of many vegetables grown at low elevations. The following are crops found to be severely affected by this mite: Beet, chard, pepper, tomato, green bean, eggplant, white mustard, watercress, potato, sweetpotato, soybean, and papaya. *(Holdaway, Look, Nishida)*

Other Miscellaneous Insects

The following additional insects have been prominent:

Insect	Remarks
Lantana butterfly *(Thecla echion)*	The larvae have caused injury to terminals, blossoms, and fruits of eggplant; they have also been found attacking foliage of potato.
Tomato russet mite *(Phyllocoptes destructor)*	An eriophyid mite, which has been identified as the very serious tomato mite of California, was first recorded causing devastating injury to tomatoes in Manoa Valley, Honolulu. It was later recorded also causing severe injury to tomato plants at Waimanalo.
Sorghum midge *(Contarinia sorghicola)*	Sorghum midge has caused serious injury to sorghum in many sections of the Island of Oahu and also on Maui.
Nysius nigriscutellatus	This lygaeid bug was abundant on many crops growing at low elevations on the Island of Oahu during the spring of 1942. It was recorded on pepper, beet, amaranth, spinach, and broccoli.
Harlequin cabbage bug *(Murgantia histrionica)*	Harlequin cabbage bug has extended its range on Oahu to Waialua in the northwest and to Honolulu in the south. It has also been recorded by an officer of the Board of Agriculture on Kauai.

(Holdaway, Nishida, Look)

BLOWFLY ATTACK ON YOUNG CALVES

During 1940, when many young calves died on Kauai, investigation revealed that attack by blowflies was the cause. The attack, known as "fly strike," consists of the development, on the living calf, of larvae or maggots hatched from eggs deposited on the calf by adult blowflies. The larvae live on the surface layers of the skin, which becomes raw and malodorous. The hair becomes matted, and, with the surface layers of the skin, comes away from the body. The attacked calf becomes dejected and usually lies down. It is commonly ignored by the mother, and if not found and suitably treated, dies in a few days.

Three species of fly have been involved, the oriental blowfly, *Chrysomyia megacephala,* the greenbottle fly or European blowfly, *Lucilia sericata,* and the Australian green blowfly or "hairy maggot" fly, *Chrysomyia rufifacies.* The information available was insufficient for a satisfactory conclusion on the relative importance of the three species. All three species visit and normally breed in carcasses and other animal matter.

It was found that calves were most commonly attacked during the first week of life, less commonly during the second week, and only occasionally in

Figure 24.—Young calf showing the combined effects of repeated blowfly "strikes" and an irritating fly spray used as a dressing. The affected area, devoid of hair, raw and cracking, extends from the back to the belly and from the shoulder to the hip.

the third week. Apparently calves may be attacked on almost any part of the body—on the shoulder, back, rump, or tail, in the nose, ears, or rectum, on the navel, or between the legs and the body.

Sheep are commonly attacked by blowflies in Hawaii, and ranchers have in the past been accustomed to occasional attacks on other animals. Such other animals were commonly sick or wounded. Only during the last year or two, however, has attack on young calves been noticed; the incidence of attack was greater during 1940 than at any other time.

Death of calves has been primarily due to two factors: First, that attack often occurred without the knowledge of the ranchers (the calves were often dead or almost dead when found); and second, no satisfactory dressing was available to ranchers for treating attacked calves. Many calves died because fly sprays and other irritating materials, applied to the attacked area, accentuated the condition. Although the maggots present were commonly killed by these materials, the accentuated condition led to the development of additional strikes.

Experimental trials have been made of two dressings, a glycerin-diborate dressing developed in Australia[13] for fly strike of sheep and the benzole-diphenylamine treatment developed in the United States[14] for treatment of

[13] Freney, M. R. *et al.* A note on new dressings for fly-struck sheep. Jour. Council Sci. and Indus. Res. 8: 161. 1935.

[14] Melvin, Roy, *et al.* diphenylamine as a wound protector against screw worm, *Cochliomyia americana*. U. S. Dept. Agr. Bur. Ent. and Plant Quar. Cir. E-481. 4 pp. 1939.

screw worm. Both have been found satisfactory. Additional dressings are being studied as occasion offers.

A survey of the ranches of Kauai has shown that during 1940 strikes on young calves occurred in 16 ranches out of 29; 150 calves were struck, and 86, or 57 percent, died. On the ranches on which strikes occurred, 15.6 percent of the calves born were struck and 9 percent died. Strikes did not occur in the hot, dry climatic zones, nor in the moderately warm, moist sections. They occurred predominantly in the moderately warm and wet sections (climatic Zone D_1 of Ripperton and Hosaka). Maximum attack occurred in the wetter sections of the Lihue district and in the wetter sections of the Kapaa homestead area.

While there were some strikes in every month of the year, they were in general least serious in the summer months. They increased to a maximum in the fall and early winter months, September to December inclusive—months when rainfall was high. *(Holdaway)*

Nutrition

Under normal conditions Hawaiian agriculture produces a wide variety of tropical and temperate-zone food crops which, combined with the fresh and processed foods brought in from the Mainland, provide a diversified, healthful diet.

However, now that war supplies have first call on available shipping and emphasis is being placed on local production of food, it has become the chief aim of the nutrition division of this station to encourage use of those local crops that best supply various nutritive elements essential to health. To this end the division has published Bulletin No. 88, Food for Health in Hawaii (Miller, Lind), which presents in popular form some of the results of scientific findings on local foods as well as general recommendations for choosing a good diet.

Progress Notes No. 36, Vitamin Values of Hawaiian Grown Fruits and Vegetables (Miller, Louis, Yanazawa), also recently issued, summarizes findings over a period of years on vitamin values of approximately 100 foods produced in Hawaii.

Probably nothing short of war could have made residents of Hawaii so interested in growing vegetables and fruits. Rapidly expanding "victory" gardens are a fine testimonial not only to the local spirit of cooperation but to recognition by the general public of the health value of fresh garden foods. That fruits and vegetables grown in Hawaii can adequately supply vitamin and mineral requirements has been well demonstrated by the division of foods and nutrition of this station.

Emergency Vegetable Crops

Analyses of some vegetables that are commonly produced in Hawaii and that are being especially recommended for emergency production are summarized in table 27. In general the mineral values for cabbages, carrots, sweetpotatoes, and tomatoes compare favorably with those reported elsewhere. *(Miller, Louis)*

Oxalates in Hawaiian-Grown Vegetables

Investigators elsewhere have shown that relatively large quantities of oxalates prevent the utilization of calcium in such vegetables as common and New Zealand spinach. Average servings of foods high in oxalates, however, do not interfere with calcium utilization of other foods. Foods high in oxalate may be valuable in the diet for other reasons, such as their vitamin A and iron contents.

The leaves of certain plants belonging to the Chenopodiaceae or goosefoot family—namely, Swiss chard, spinach, beet tops, and lamb's quarter—have been reported to contain relatively large proportions of oxalic acid in the form of oxalates. A few plants in other families have also been found to be high in oxalates. The figures for oxalic acid given here confirm published reports on the amount of oxalates in beet tops, purslane, and spinach. In addition, amaranth *(Amaranthus gangeticus)* and Malabar nightshade *(Basella rubra)*, members of plant families closely related to the Chenopodiaceae, were found to contain such relatively large quantities of oxalates that the calcium in them is probably unavailable.[1]

Table 27.—Analyses of Hawaiian-grown vegetables recommended as emergency food crops

Vegetable	Proximate composition					
	Water	Protein (N × 6.25)	Ether extract (fat)	Crude fiber	Carbohydrates (by difference)	Total ash
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Cabbage, headed	93.0	1.2	0.1	0.6	4.6	0.53
Carrot	86.0	2.1	.1	1.0	9.5	1.31
Sweetpotato, New Era	68.5	1.9	.1	.7	27.9	.98
Sweetpotato, No. 35.14, yellow	67.4	2.3	.1	.8	28.3	1.15
Sweetpotato, No. 35.23, orange	76.5	1.4	.1	.9	20.2	.97

	Mineral composition			
	Total ash	Calcium (Ca)	Phosphorus (P)	Iron (Fe)
	Percent	*Percent*	*Percent*	*Percent*
Cabbage, headed	0.53	0.049	0.020	0.00029
Carrot	1.31	.044	.137	.00055
Sweetpotato, New Era	.98	.027	.037	.00041
Sweetpotato, No. 35.14, yellow	1.15	.026	.039	.00036
Sweetpotato, No. 35.23, orange	.97	.041	.037	.00038
Tomato, pear-shaped variety (with skin)	.60	.008	.024	.00033
Tomato (without skin)	.60	.007	.024	.00030

Luau (taro tops), a favorite Hawaiian green and an excellent source of calcium, contained less than half the amount of oxalic acid of amaranth and

[1] Information relating to plant families furnished by Dr. Harold St. John, Botany Department, University of Hawaii.

beet tops on the fresh cooked basis and only about one-fifth the amount on the dry basis. Sweetpotato tops, another green recommended for calcium content, contained about one-half as much oxalic acid as taro tops. Japanese taro (dasheen) was found to contain more oxalic acid than common Hawaiian taro. About half the vegetables tested—some of them good sources of calcium—contained negligible amounts of oxalic acid. The results of analyses for oxalic acid are given in table 28. *(Miller, Loo)*

Table 28.—Oxalic-acid contents of 19 Hawaiian-grown vegetables

Vegetable		Oxalic-acid contents	
Common name	Scientific name	On moist-cooked basis	On dry basis
Amaranth, short-stemmed variety	Amaranthus gangeticus	0.88	9.24
Beet tops	Beta vulgaris	.87	13.15
Purslane	Portulaca oleracea	.82	13.36
Amaranth, long-stemmed variety	Amaranthus gangeticus	.74	9.50
Spinach	Spinacia oleracea	.67	6.09
Malabar nightshade	Basella rubra	.56	7.85
Hawaiian taro, leaves	Colocasia esculenta	.36	2.01
Sweetpotato tops	Ipomoea batatas	.18	1.27
Horseradish tree, leaves and tender tips	Moringa oleifera	.08	.30
Japanese taro (dasheen)	Colocasia esculenta	.06	2.45
Hawaiian taro cooked corm	do	.013	.044
Lettuce, hort. var. Mignonette	Lactuca sativa	.006	.140
Leaf mustard cabbage	Brassica juncea	.003	.046
Asparagus	Asparagus offinalis	.003	.035
Turnip greens	Brassica rapa	.002	.027
Watercress	Nasturtium officinale	.001	.026
White mustard cabbage	Brassica chinensis	.001	.013
Head cabbage	Brassica oleracea	.0005	.006
Swamp cabbage	Ipomoea aquatica	[1] .0	.0
Chinese cabbage	Brassica pe-tsai, B. pekinensis	[1] .0	.0

[1] If present, the oxalic-acid content was too small to be determined.

Vitamin C of Tomatoes

Questions occasionally arise as to the relative nutritive values of Hawaiian and mainland produce. Investigations usually show the Hawaiian product to be equal, if not superior, to that grown elsewhere.

Preliminary studies of the ascorbic acid of Hawaii- and mainland-grown tomatoes covered a period during the fall and early winter, when values are generally low. The results, however, indicated no significant differences between the two types of material at this season. Nineteen samples of mature-green Maui-grown tomatoes, selected between the months of October and February, gave a mean value for ascorbic acid of 13.6 $\pm$ 0.75 milligrams per 100 grams. The comparable value for 12 samples of mainland fruits procured from Honolulu markets between October and December was 14.7 $\pm$ 0.83 milligrams.

No definite seasonal trend in vitamin content of either group was apparent during the short period in which samples were taken, and considerable variation was found within each group.

Two samples of tomatoes grown on Oahu and analyzed in February were found to contain 12.8 milligrams ascorbic acid per 100 grams. Three samples of plum tomatoes (a small, heavy-fruiting type grown extensively in home gardens during the summer months), analyzed in July and October, contained approximately 27 milligrams per 100 grams. *(Miller, Louis)*

Vitamin C of Papaya

Weekly tests over a period of a year have proved that Solo papayas from two localities on the Island of Oahu are excellent sources of ascorbic acid, or vitamin C. Forty-five papayas from Poamoho Experimental Farm contained an average of 81 $\pm$ 1.7 milligrams of ascorbic acid per 100 grams of edible papaya (range 60-122 mg.), and 40 from Kailua contained an average of 88 $\pm$ 2.5 milligrams (range 59-118 mg.).

One sample of fresh papaya seeds, including the aril, was tested for vitamin C and found to contain 78 milligrams ascorbic acid per 100 grams of seed; the papaya from which the seeds were taken had a value of 93 milligrams ascorbic acid.

Two samples of the aril (the fleshy material surrounding the black seeds) were tested and found to have 130 and 161 milligrams ascorbic acid per 100 grams; the fruits from which these samples were taken contained 72 and 98 milligrams, respectively.

To determine the loss of vitamin C in papaya due to cooking, the ascorbic-acid contents of two samples of papaya in the fresh state, one from Kailua and one from Poamoho, were compared with those of half of the same papayas baked in an electric oven at 350° F. for 20 to 25 minutes. One

sample lost 7 and the other, 12 percent. Cooking directions often call for the addition of lemon or lime juice, which will increase the acidity and probably improve the retention of ascorbic acid in heated papaya. The *p*H value for three samples of papaya was found to be 6.0.

A sauce made by simmering papaya with a little sugar for 20 minutes lost 7 percent of the original ascorbic acid. *(Miller, Louis)*

Mangoes as a Source of Vitamin C

The vitamin C of mangoes appears to vary greatly with the variety. Of the samples tested, the common mango (Manini) had the highest value, or 114 milligrams ascorbic acid per 100 grams of fruit, followed by the Wootten with 90 milligrams, Bishop with 33 milligrams, and the Haden and Pirie with 14 milligrams. Although they were fruits of superior flavor and texture, four samples of Pirie mangoes collected from three locations in two seasons showed low ascorbic-acid values. Green mangoes of all varieties tested contained more vitamin C than ripe ones. *(Miller, Louis)*

Vitamin A Content of Livestock Feeds

Pineapple bran, an important stock feed in the Islands, has been found to have a vitamin A value of approximately 13,000 International Units per pound, equivalent to the value reported by the United States Department of Agriculture (1939 Yearbook, p. 843) for alfalfa meal. (Alfalfa leaf meal has three to seven times as much vitamin A.)

Kiawe-bean meal, made from the seed pods of the algaroba or kiawe tree, which is used in some sections of the Islands as a feed for stock, was found to have only about one-eighth of the vitamin A content of pineapple bran, or 157 International Units of vitamin A per pound. *(Miller, Yanazawa)*

Carbon-Disulfide Treatment for Cereals

To reduce spoilage from weevils and other insects in storing foods for possible emergency use, the nutrition division has recommended that some foods, specially whole-grain cereals, be treated with small quantities of carbon disulfide under carefully controlled conditions. No record could be found in the literature to indicate whether such a procedure would destroy the thiamin content of whole-grain products. Therefore, three cereals—brown rice, wholewheat flour, and rolled oats—were tested before and after treatment with small quantities of carbon disulfide. The cereals were purchased on the retail market. In each case the product was thoroughly mixed and one half of the quantity was placed in airtight containers, kept at room temperature, and assayed without treatment. Samples of from 1 to 2 pounds of each product were placed in separate containers that could be made air-

tight, 1 teaspoon of carbon disulfide in a small evaporating dish was placed on top of the cereal, and the tightly closed cans were allowed to stand for 24 hours. Then the lids were removed and the cans, covered with cheese cloth, were allowed to stand until the volatilized carbon disulfide had escaped and the cereals had no odor (1 to 2 days).

The treated and untreated cereals were fed to groups of rats from the same litters with suitable positive and negative controls. The rice was fed in the cooked state; the wholewheat flour and the rolled oats, in the uncooked state.

Brown rice cooked in oriental fashion contained 95 micrograms thiamin per 100 grams (in the dry state, 224 micrograms per 100 grams). The wholewheat flour contained 350 micrograms per 100 grams, and the rolled oats, 430.

The growth response of groups of rats indicated that little or no destruction results from treating brown rice, wholewheat flour, and rolled oats with carbon disulfide to destroy insects. *(Miller, Yanazawa)*

Sugar Content of Carrots

Two varieties of carrots, Imperator and Danvers Half Long, planted at Poamoho in October 1941, were analyzed for glucose and sucrose at four stages of maturity (harvested at 101, 110, 122, and 145 days). The data are summarized in table 29.

Table 29.—Sugar content of Hawaiian-grown carrots

Period from planting to harvest	Imperator					
	Glucose		Sucrose		Total sugars	
	Wet basis	Dry basis	Wet basis	Dry basis	Wet basis	Dry basis
Days	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
101	3.58	23.10	3.76	24.20	7.34	47.30
110	2.51	17.57	3.92	27.40	6.43	44.97
122	2.66	16.44	4.09	25.23	6.75	41.67
145	1.84	14.01	3.74	28.58	5.58	42.59
Period from planting to harvest	Danvers Half Long					
	Glucose		Sucrose		Total sugars	
	Wet basis	Dry basis	Wet basis	Dry basis	Wet basis	Dry basis
Days	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
101	3.94	30.78	2.47	19.32	6.41	50.10
110	2.58	20.61	2.83	22.60	5.41	43.24
122	3.06	23.6	3.16	24.3	6.22	47.90
145	2.16	19.33	2.49	22.20	4.65	41.53

Even though sucrose is sweeter than glucose, the increase in sucrose may not be sufficient to offset the general decrease in total sugars with age. No attempt was made to test other factors that may affect quality but, on the basis of total sugars, the younger carrots would be more desirable from the culinary standpoint. *(Miller, Loo)*

Family-Living Studies

Eighty-four families cooperated during the year 1940-41 in the study of family food habits and adequacy of diets, bringing the total families included in this study to 187. From the 4-week records of food consumption, the adequacy of the family diets was calculated in terms of calories, protein, calcium, phosphorus, iron, and vitamins A, B, and C.

The most common, and most serious, deficiencies were the inadequate intakes of calcium and of vitamin B. Other, and less serious, deficiencies were in vitamins A and C, iron, and protein. Very few of the family diets were adequate in all eight of the nutritive essentials studied, and some were adequate in none of the eight. These marginal and submarginal diets undoubtedly are reflected in the physical and dental status of the children in these families.

There were few really serious cases of poor health and malnutrition among rural children, whose diets as a rule are better than those of the city families studied. But about half of the children, chiefly those in the 2-to-10-year age group, showed some effects of previous or current malnourishment.

The average dental condition of the 600 children examined was worse than that of similar age groups in mainland United States.

A study of the diets indicates that low vitamin and calcium consumption contributes to the poor dentition common among these rural and city children in Hawaii. It has been suggested that the low fluorine content reported for drinking waters in most sections of the Territory may also be a factor.

The dental condition of children living in the rural districts of East Maui was much better than that of children in rural Oahu, Kona, and Honolulu. The diets of the rural Maui children were higher in local and home-grown foods and lower in refined, processed commercial foods than were the diets in the three other areas studied.

In most cases deficient diets were due not to inadequate funds but to poor choice of foods—the choice of refined sweets and other carbohydrates, expensive muscle cuts of meat, and canned foods, rather than of whole-grain cereal products, fresh fruits, vegetables, and milk. The dietary deficiencies revealed by these studies make apparent the need for more widespread nutritional education in Hawaii. *(Potgieter)*

Appendix

PUBLICATIONS

Report

Beaumont, J. H. *Report of the Hawaii Agricultural Experiment Station, 1940.* 94 pp., illus. 1941.

Bulletin

No. 86. Payne, John H., Ley, Gaston J., and Akau, George. *Processing and Chemical Investigations of Taro.* 42 pp., illus. 1941.

87. Jones, Winston W., Storey, W. B., Parris, G. K., and Holdaway, F. G. *Papaya Production in the Hawaiian Islands.* 64 pp., illus. 1941.

Circular

No. 17. Jones, Winston W. *Methyl-Bromide Fumigation of Papaya and Tomato.* 14 pp., illus. 1940.

18. Parris, G. K. *Diseases of Taro in Hawaii and their Control, with Notes on Field Production.* 29 pp., illus. 1941.

19. Bice, C. M., and Tower, B. A. *Battery Management of Chicks and Layers in Hawaii.* 23 pp., illus. 1942.

20. Bice, C. M. *Dubbing Production-Bred Single-Comb White Leghorns.* 8 pp., illus. 1942.

Technical Paper

No. 44. Parris, G. K., and Jones, Winston W. *Studies on the Nature of Spindling Sprout of Potato.* Phytopathology 31(4):340-346, illus. 1941.

52. Hamre, Christopher J., and Wong, Kamehameha K. L. *Hematologic Values for Normal Children Three, Four and Five Years of Age Living in Hawaii.* Amer. Jour. Dis. Children 60:22-35, illus. 1940.

57. Jones, Winston W., and Kubota, Hisashi. *Some Chemical and Respirational Changes in the Papaya Fruit During Ripening, and the Effects of Cold Storage on These Changes.* Plant Physiol. 15:711-717, illus. 1940.

58. Hamre, Christopher J., and Au, Man Hing. *Hematologic Values for Normal Healthy Men 16 to 25 Years of Age.* Jour. Lab. and Clin. Med. 27(10):1231-1244, illus. 1942.

61. Potgieter, Martha. *Taro* (Colocasia esculenta) *as a Food.* Amer. Dietet. Assoc. Jour. 16(6):536-540. 1940.

62. Potgieter, Martha. *The Utilization of the Calcium and Phosphorus of Taro by Young Rats.* Amer. Dietet. Assoc. Jour. 16(7): 670-673. 1940.

63. Potgieter, Martha. *The Utilization of the Calcium and Phosphorus of Taro by Young Women.* Amer. Dietet. Assoc. Jour. 16(9):898-904. 1940.

64. Clements, Harry F., and Akamine, Ernest. *Root Stimulation in Sugar Cane* (Saccharum officinarum) *with Special Reference to the Effects of Ethyl Alcohol.* Amer. Jour. Bot. 27(7):482-487, illus. 1940.

65. Fukunaga, Edward T., and Dean, L. A. *Suction Filtration Apparatus for Sampling Filtrates under Constant Pressure.* Indus. and Engin. Chem., Analyt. Ed. 12:471, illus. 1940.

66. Michener, H. David. *Shortening of Dormancy in Potato Tuber.* Amer. Soc. Hort. Sci. Proc. 38:523-529. 1940.

67. Cooil, Bruce J. *Significance of Phloem Exudate of* Cucurbita pepo *with Reference to Translocation of Organic Materials.* Plant Physiol. 16:61-84, illus. 1941.

69. Yoshida, Ruth Kojima. *Studies on Organic Phosphorus Compounds in Soil; Isolation of Inositol.* Soil Sci. 50(2):81-88, illus. 1940.

70. Holdaway, F. G. *Differential Susceptibility of Varieties of Garden Bean to Oviposition by Melon Fly,* Dacus cucurbitae coq. Hawaii. Ent. Soc. Proc. 10(3):421-422. 1940.

71. Alicata, Joseph E. *Studies on Control of the Liver Fluke of Cattle in the Hawaiian Islands.* Amer. Jour. Vet. Res. 2(3):152-164, illus. 1941.

72. Machlis, Leonard. *Accumulation of Arsenic in the Shoots of Sudan Grass and Bush Bean.* Plant Physiol. 16(3):521-544, illus. 1941.

73. Clements, Harry F. *Integration of Climatic and Physiologic Factors with Reference to the Production of Sugar Cane.* Hawaii. Planters' Rec. 44:201-233, illus. 1940.

74. Clements, Harry F. *Movement of Organic Solutes in the Sausage Tree,* Kigelia africana. Plant Physiol. 15:689-700, illus. 1940.

76. Ayres, A. S. *Sorption of Potassium and Ammonium by Soils as Influenced by Concentration and the Degree of Base Saturation.* Soil Sci. 51(4): 265-272, illus. 1941.

77. Holdaway, F. G., and Look, William C. *Insects of the Garden Bean in Hawaii.* Hawaii. Ent. Soc. Proc. 12(2): 249-260. 1942.

78. Parris, G. K., and Jones, W. W. *The Use of Methyl Bromide as a Means of Detecting Latent Infections by* Colletotrichum *spp.* Phytopathology 31(6): 570-571, illus. 1941.

80. Miller, Carey D., and Louis, Lucille. *Chemical Analyses and Vitamin Assays of Macadamia Nuts.* Food Res. 6(6): 547-552, illus. 1941.

81. Parris, G. K. *Eye-Spot of Napier Grass in Hawaii Caused by* Helminthosporium sacchari. Phytopathology 32(1): 46-63, illus. 1942.

82. Parris, G. K., and Ripperton, J. C. *Reactions of Napier Grass, Merker Grass, and Their Crosses to Helminthosporium Eye Spot.* Phytopathology 31(9): 855. 1941.

83. Okubo, S., Lyman, C., and Dean, L. A. *Some Considerations of the Polarographic Method of Quantitative Analysis.* Hawaii. Planters' Rec. 45: 67-78, illus. 1941.

84. Hamre, C. J., and McHenry, J. T. *Methods of Obtaining Blood of Fowl for Complete Blood Examinations.* Poultry Sci. 21(1): 30-34. 1942.

85. Ballard, Stanley S., and Dean, L. A. *Soil Studies with Radioactive Phosphorus: Significance of Biological Measurements of the Retention of Applied Phosphorus by Soils.* Soil Sci. 52(3): 173-183, illus. 1941.

86. Parris, G. K. Phytophthora parasitica *on Papaya* (Carica papaya) *in Hawaii.* Phytopathology 32(4): 314-320, illus. 1942.

87. Ayres, A. S. *Sorption of Potassium and Ammonium by Hawaiian Soils.* Hawaii. Planters' Rec. 45: 93-106, illus. 1941.

88. Bice, C. M., and Dean, L. A. *Utilization of Urea Nitrogen by Growing Chicks.* Poultry Sci. 21(1): 15-17. 1942.

89. Alicata, J. E., and Swanson, L. D. *Observations on the Longevity of the Liver Fluke,* Fasciola gigantica, in *Cattle.* Amer. Jour. Vet. Res. 2(5): 417-418. 1941.

90. Hamre, C. J., and McHenry, J. T. *Blood Values of Hens Fed a Yeast-Fermented Mash Supplemented Adequate Diet.* Poultry Sci. 21(4): 333-339, illus. 1942.

92. Clements, Harry F., Martin, J. P., and Moriguchi, S. *Composition of Sugar Cane Plants Grown in Deficient Nutrient Solutions.* Hawaii. Planters' Rec. 45:227-239, illus. 1941.

93. Alicata, Joseph E: *Experimental Transmission of Endemic Typhus Fever by the Sticktight Flea,* Echidnophaga gallinacea. Wash. Acad. Sci. Proc. 32(2):57-60, illus. 1942.

97. Clements, Harry F., and Kubota, T. *Internal Moisture Relations of Sugar Cane—the Selection of a Moisture Index.* Hawaii. Planters' Rec. 46:17-36, illus. 1942.

98. Jones, Winston W. *Respiration and Chemical Changes of the Papaya Fruit in Relation to Temperature.* Plant Physiol. 17(3): 481-486, illus. 1942.

99. Tanada, T., and Dean, L. A. *Boron in Some Hawaiian Soils and Crops.* Hawaii. Planters' Rec. 46(2):65-74, illus. 1942.

Miscellaneous

Parris, G. K. *Comparison of Rates of Apparent Photosynthesis and Respiration of Diseased and Healthy Bean Leaflets.* Jour. Agr. Res. 62(3):179-192, illus. (Thesis, Ph. D., Cornell Univ.) 1941.

Siu, Ralph. *Vegetative Propagation of the Pineapple.* [Unpublished master's thesis. Copy on file Libr., Hawaii Univ., Honolulu.] 1941.

Balls, A. K., Thompson, R. R., and Jones, W. W. *Crude Papain, Preparation and Properties.* Indus. and Engin. Chem. 32:1144-1147. 1940.

Chandler, A. C., Alicata, J. E., and Chitwood, M. B. *Life History (Zooparasitica). II. Parasites of Vertebrates. In* An Introduction to Nematology 2(2):267-301. Babylon, N. Y. 1941.

Progress Notes

No. 15. Parris, G. K., and Ripperton, J. C. *A New Disease of Napier Grass in Hawaii.* 11 pp. [Mimeographed.] 1940.

16. Holdaway, F. G. *Control of Corn Earworm on Tomatoes by Means of Cryolite Bait.* 3 pp. [Mimeographed.] 1940.

17. Miller, Carey D., and Louis, Lucille. *Nutritive Value of Macadamia Nuts.* 3 pp. [Mimeographed.] 1940.

18. Kikuta, K. *Anthracnose of Papaya and its Control.* 5 pp. [Mimeographed.] 1941.

19. Matsuura, M. *Damping-Off and its Control by Seed Treatment.* 5 pp. [Mimeographed.] 1941.
20. Henke, L. A., and Work, S. H. *Use of Molasses as Livestock Feed Increasing.* 6 pp. [Mimeographed.] 1941.
21. Kikuta, K., and Parris, G. K. *Propagating Taro by the Normally Dormant Buds Present on the Huli and Corm.* 9 pp. [Mimeographed.] 1941.
22. Holdaway, F. G., and Look, Wm. C. *Control of Corn Earworm on Tomatoes by Means of Cryolite Bait and Cryolite Spray.* 9 pp. [Mimeographed.] 1941.
23. Holdaway, F. G., and Look, Wm. C. *Exploratory Studies for Materials to Control Bean Pod Borer* Maruca testulalis. 7 pp. [Mimeographed.] 1941.
24. Alicata, Joseph E. *A New Drug for the Treatment of Liver Fluke of Cattle.* 4 pp. [Mimeographed.] 1941.
25. Frazier, W. A., *et al. Cultural Suggestions for Certain Vegetable Crops.* (Appendix V-A-6, No. 5, of the "Emergency Food Production Plan" prepared by the Diversified Crops Com., Hawaii. Sugar Planters' Assoc.) [48] pp., illus. [Mimeographed.] 1941.
26. Holdaway, F. G. *Insects of Sweetpotato and Their Control.* (From Appendix V-A-4, No. 5, of the "Emergency Food Production Plan" prepared by the Diversified Crops Com., Hawaii. Sugar Planters' Assoc.) 7 pp. [Mimeographed.] 1941.
27. Holdaway, F. G. *Insects of Cabbage and Their Control.* (From Appendix V-A-4, No. 5, of the "Emergency Food Production Plan" prepared by the Diversified Crops Com., Hawaii. Sugar Planters' Assoc.) 6 pp. [Mimeographed.] 1941.
28. Holdaway, F. G., *Insects of Dry Bean Crops and Their Control.* (From Appendix V-A-4, No. 5, of the "Emergency Food Production Plan" prepared by the Diversified Crops Com., Hawaii. Sugar Planters' Assoc.) 5 pp. [Mimeographed.] 1941.
29. Henke, L. A., Work, S. H., and Maruyama, Charles. *Strip Cane as a Substitute Roughage for Napier Grass, Fed to Dairy Cows Confined in Dry Lots.* 4 pp. [Mimeographed.] 1941.
30. Frazier, W. A., Sumida, D. Y., Tachibana, S., and Takahashi, M. *Recent Experiments on the Propagation of the Sweet Potato in Hawaii, Together with Notes on Varieties.* 6 pp., illus. [Mimeographed.] 1942.

31. Frazier, W. A., and Tachibana, S. *Notes on Edible Pod Cowpea Behavior in Hawaii.* 6 pp. [Mimeographed.] 1942.
32. Frazier, W. A. *Some Promising Fruitful Tomato Varieties for Hawaii Gardeners.* 3 pp. [Mimeographed.] 1942.
33. Frazier, W. A., Murphy, F. T., and Wadsworth, H. A. *Some Useful Implements for Commercial Vegetable Production.* 8 pp., illus. [Mimeographed.] 1942.
34. Henke, L. A., Work, S. H., and Maruyama, Chas. *Koa-Haole Roughage as a Substitute for Imported Protein Supplements Fed to Dairy Cows.* 6 pp. [Mimeographed.] 1942.
35. Bice, C. M., *Feedings Rabbits for Meat Production (Under Wartime Conditions in Hawaii).* 3 pp. [Mimeographed.] 1942.
36. Miller, Carey D., Louis, Lucille, and Yanazawa, Kisako. *Vitamin Values of Hawaiian Grown Fruits and Vegetables.* [10] pp. [Mimeographed.] 1942.

RESEARCH PROJECTS ACTIVE DURING THE BIENNIUM

Project No.	TITLE OF PROJECT AND SPECIALISTS IN CHARGE
50.1	Study of special problems of the production, preservation, and utilization of food and forage under war emergency conditions in Hawaii J. H. Beaumont, *et al.*
52	Kona Branch Station—general upkeep R. K. Pahau
53	Poamoho Experimental Farm—general upkeep Frank Mercado, M. L. McDougal*
54	Haleakala Branch Station—general upkeep F. T. Murphy, K. Murakami
100	General agronomic upkeep J. C. Ripperton
103	Forage crops: Adaptability, breeding, and yield studies J. C. Ripperton
108	Taro-agronomic investigations J. C. Ripperton
112	Grazing value of tropical forage species J. C. Ripperton

* Resigned

Project No.	TITLE OF PROJECT AND SPECIALISTS IN CHARGE
113	The selection and breeding of tropical sweet-corn varieties resistant to the attack of both the corn leafhopper *(Peregrinus maidis,* Ashm.) and corn earworm through inbreeding and recombination of selfed lines and by the backcrossed method of breeding M. Takahashi, E. M. Hodges*
114	A study of the factors of soil and of management affecting the growth of clovers in the moist, humid areas of Hawaiian ranges J. C. Ripperton, E. Y. Hosaka
115	Nutrition of Napier grass *(Pennisetum purpureum):* The effect of the application of certain fertilizers on the gross yield, chemical composition of the cut forage, and plant-food reserves in the crown and roots J. C. Ripperton, M. Takahashi
116	Ecology of Hawaiian ranges: A study of the distribution of plant species on the range and the environmental factors which affect distribution and succession J. C. Ripperton, E. Y. Hosaka
117	Introduction, testing, and selection of forage species J. C. Ripperton, E. Y. Hosaka
118	Management of Napier grass under grazing J. C. Ripperton, M. Takahashi
119	Management of koa haole *(Leucaena glauca)* M. Takahashi, Gordon Shigeura
120	Mechanical harvesting of tropical forage crops J. C. Ripperton, M. Takahashi
121	The conversion of forages and byproducts grown or produced in Hawaii into palatable and nutritious silage J. C. Ripperton, L. A. Henke, Gordon Shigeura
150	General horticultural upkeep W. W. Jones
151	Selection, description, and classification of avocado *(Persea americana)* and mango *(Mangifera indica)* varieties with respect to their cultural and climatic requirements in Hawaii J. H. Beaumont, W. W. Jones, W. B. Storey

* Resigned

Project No.	TITLE OF PROJECT AND SPECIALISTS IN CHARGE
152	Inheritance of fruit characters and of sex in the papaya *(Carica papaya)* W. B. Storey
153	Asexual propagation of tropical plants with special reference to macadamia, litchi, lungan, and mangosteen W. W. Jones, W. Ikeda
157	Introduction and testing of tropical fruits and nuts in Hawaii W. B. Storey, W. W. Jones, J. H. Beaumont
159	A physiological study of blossom-bud formation, flowering, and fruiting with special reference to macadamia, mango, and litchi J. H. Beaumont, W. W. Jones, W. Ikeda
161	Varietal, stock, and adaptation studies with citrus J. H. Beaumont
162	The determinations and inheritance of quality in the macadamia nut *(Macadamia ternifolia* and *M. ternifolia* var. *integrifolia)* W. B. Storey, W. W. Jones
163	Variety test and improvement of small fruits J. H. Beaumont
164	Tropical fruits: Ripening, disinfestation treatments, and storage W. W. Jones, L. Shaw
166	Coffee yields and grade as influenced by pruning and cultural methods J. H. Beaumont
167	Potato-seed storage in Hawaii W. A. Frazier
168	The carbohydrate and mineral nutrition of papaya with special reference to sex expression W. W. Jones, W. Ikeda
169	A study of cultural methods and water relations in the growth of papaya W. W. Jones
200	General dairy upkeep L. A. Henke
203	Comparative value of various grasses and legumes grown in the tropics as roughages for dairy cattle and most effective and economical way of utilizing such roughages L. A. Henke

Project No	TITLE OF PROJECT AND SPECIALISTS IN CHARGE
204	The use of nonprotein nitrogen as protein substitutes in the nutrition of cattle and swine L. A. Henke, S. H. Work
265	Feeding experiments with dairies and ranches designed to more fully determine the possibilities of using locally grown feeds and local byproducts for livestock nutrition, chiefly milk, beef, and pork production L. A. Henke, S. H. Work
266	Digestibility experiments to determine the nutritive value for livestock of various local feeds S. H. Work
271	General piggery upkeep S. H. Work, L. A. Henke, L. E. Harris*
272	Protein supplements in swine rations, with special reference to fish meal and roasted soybeans S. H. Work, C. Maruyama, L. A. Henke
273	The value of cane molasses and other feeds and byproducts of Hawaiian industries as supplements to fattening rations for swine S. H. Work, C. Maruyama
274	The nutritive requirements of lactating sows S. H. Work, C. Maruyama, L. E. Harris*
275	Determination of the nutritive value, by actual feeding trials, of local ensilages L. A. Henke, S. H. Work, C. Maruyama
400	General poultry upkeep C. M. Bice
408	Batteries for laying and breeding stock C. M. Bice
413	Island-grown feeds and byproducts in poultry rations C. M. Bice
414	Poultry houses for Hawaii C. M. Bice
415	Breeding for high egg production and resistance to disease C. M. Bice

* Resigned

Project No.	TITLE OF PROJECT AND SPECIALISTS IN CHARGE
500	General nutrition upkeep C. D. Miller, M. Potgieter†
501	A study of the nutritive value of foodstuffs in Hawaii by means of chemical analyses and biological experiments C. D. Miller, L. Louis*
506	Anemia studies: The relation of blood constituents and blood-forming organs in nutritional anemia C. J. Hamre, C. D. Miller
509	Total family expenditures, total cost of food, adequacy of diets, and the physical and dental status of children of various groups of people in Hawaii M. Potgieter†
510	The available iron of Hawaiian vegetables C. D. Miller, L. Louis*
600	General chemistry and soils upkeep L. A. Dean
602	The design of apparatus for measuring the moisture content-surface force relationships in soils and a study of the factors affecting that relationship H. A. Wadsworth
613	The rate of mineralization of soil nitrogen and the soil factors influencing this process L. A. Dean, E. Fukunaga*
615	The nature and identification of the constituents of organic and inorganic soil colloids formed under Hawaiian weathering conditions L. A. Dean
616	The nature of soil phosphorus L. A. Dean, R. Yoshida
617	The minor elements in Hawaiian soils and their relation to the growth of economic plants in Hawaii L. A. Dean
618	A study of the properties of acid Hawaiian soils A. S. Ayres

* Resigned
† On leave

Project No.	TITLE OF PROJECT AND SPECIALISTS IN CHARGE
619	Koa haole *(Leucaena glauca)* investigations: A chemical and physiological study of the nature and properties of the toxic principle or depilatory agent present R. Yoshida
651	Arsenic toxicity to plants H. F. Clements, T. Kubota
652	A study of certain factors affecting the germination and viability of seeds in Hawaii H. F. Clements, E. K. Akamine
653	The growth of *Saccharum officinarum* as affected by light conditions and time of planting H. F. Clements, E. K. Akamine, T. Kubota
654	Studies of movement and storage of plant solutes with respect to growth processes H. F. Clements, G. Yuen*, E. K. Akamine, T. Kubota
801	Plant pathological investigations on the crops of the Hawaiian Islands G. K. Parris†, W. A. Frazier, K. Kikuta
803	Investigations on the diseases of tomato: Their cause and control G. K. Parris†, K. Kikuta, M. Matsuura
804	Investigations on the diseases of potato and their control in Hawaii G. K. Parris†, K. Kikuta, M. Matsuura
805	A study of infection phenomena of *Carica papaya* (papaya) by *Colletotrichum gloeosporioides* G. K. Parris†, M. Matsuura
806	Properties of a virus disease of papaya G. K. Parris†, M. Matsuura
807	Potato cultural investigations in Hawaii W. A. Frazier
809	Variety tests of truck crops W. A. Frazier, D. Y. Sumida*
810	Vegetable genetic and breeding investigations W. A. Frazier, D. Y. Sumida

* Resigned
† On leave

Project No.	TITLE OF PROJECT AND SPECIALISTS IN CHARGE
901	Study on parasitic diseases of cattle with special reference to the life history and control of parasites of the liver, intestinal tract, and skin J. E. Alicata, A. C. Cuckler
903	The effect of nutrition on the susceptibility of chickens to roundworm and tapeworm infections J. E. Alicata, A. C. Cuckler
905	Life cycle, economic importance, and control of the cecal worm, *Subulura brumpti,* of poultry J. E. Alicata, A. C. Cuckler
950	General entomology upkeep F. G. Holdaway, W. C. Look
951	The ecology of the tomato bug *Cyrtopeltis varians (Engytatus geniculatus)* F. G. Holdaway, W. C. Look
952	The biological control of cabbage worm, *Pontia* (Pieris) *rapae* (L.) F. G. Holdaway, E. Lucas*
953	An ecological study of the insects of papaya with special reference to possible vectors of papaya mosaic F. G. Holdaway, W. C. Look, T. Nishida
954	Control of insects of truck crops F. G. Holdaway, W. C. Look, E. Lucas*
JP-1	A study of factors influencing annual yields and grade of coffee in Kona with particular reference to pruning, and fertilization, and to the values and costs involved J. H. Beaumont, L. A. Dean

* Resigned

FISCAL STATEMENT—1940-1942

RECEIPTS

	Federal Acts				Territorial			
	Hatch	Adams	Purnell	Bankhead-Jones	Bankhead-Jones Offset	Special	Grant for soil research	Total
Receipts from the Treasury of the United States	$30,000.00	$30,000.00	$75,000.00	$18,372.80				$153,372.80
Receipts from Territorial funds					$18,372.80	$146,890.70		165,263.50
Receipts from sales						47,773.51		47,773.51
Receipts from other sources							$1,240.01	1,240.01
Total receipts	$30,000.00	$30,000.00	$75,000.00	$18,372.80	$18,372.80	$194,664.21	$1,240.01	$367,649.82

DISBURSEMENTS

Personal services	$24,833.05	$27,853.31	$71,117.61	$15,353.78	$13,590.47	$128,284.47	$ 765.00	$281,797.69
Supplies and materials	1,679.01	1,140.57	2,501.56	2,728.19	1,618.97	35,174.48	177.44	45,020.22
Communication service	10.30				68.20	1,962.49		2,040.99
Travel expenses			2.90		51.75	2,000.74		2,055.39
Transportation of things	2.50	16.45	5.70	14.21		370.29	2.50	411.65
Printing and publications	1,348.93				1,225.41	1,488.55		4,062.89
Heat, light, water and power	635.46		1.50		243.35	6,395.65		7,275.96
Contingent expenses	10.00			5.28		11,242.11		11,257.39
Equipment	1,480.75	570.11	1,370.73	180.26	1,574.65	5,449.61	64.55	10,690.66
Structures and non-structural improvements				91.08		2,295.82		2,386.90
Balance unexpended, June 30, 1942		419.56					230.52	650.08
Total disbursements	$30,000.00	$30,000.00	$75,000.00	$18,372.80	$18,372.80	$194,664.21	$1,240.01	$367,649.82